DUPLICATE

Forecasting Research

Forecasting Research Division
Technical Report No. 211

INVESTIGATION INTO SATELLITE WINDS-III. CURRENT STATUS AND RECOMMENDATIONS

by

P Butterworth

February 1997

Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ
United Kingdom

ORGS UKMO F

National Meteorological Library
FitzRoy Road, Exeter, Devon. EX1 3PB

Forecasting Research
Technical Report No. 211

INVESTIGATION INTO SATELLITE WINDS- III. CURRENT STATUS AND RECOMMENDATIONS

by

P. Butterworth

February 1997

Forecasting Research
Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ
United Kingdom

© Crown Copyright 1997

Permission to quote from this paper should be obtained from the above Meteorological Office division.

INVESTIGATION INTO SATELLITE WINDS — III. CURRENT STATUS AND RECOMMENDATIONS

P. Butterworth, NWP Division, UKMO, Bracknell

Abstract

Routine observations for input into UKMO NWP arrive daily via the GTS. One particular type of observation is the 'satellite wind'. This observation type has more commonly been thought of as a cloud-motion wind, given that the parameter it attempts to measure is that of wind speed at a particular height level, as deduced from scrutiny of the movement of clouds. The advent of satellite winds derived from water vapour channels, as well as infrared and visible, means that clouds are no longer the only tracers able to be followed, and that the concept of a wind at a single level becomes even more blurred than it was previously. This report is the third of a set of three and assesses the current status and quality of satellite winds, with the quality statistics derived in comparison with a UM background field. It also includes recommendations for the improvement of the use of satellite winds within UKMO.

Part I deals with the currently known methods of production of satellite winds from each of the geostationary satellite operators. Part II looks at the treatment of satellite winds at UKMO, through observation preprocessing, quality control, assimilation and observation monitoring.

Contents

1 Current status of satellite wind production 2

2 Current coverage of satellite winds 4

3 Current quality of satellite winds 4

3.1 UKMO satellite wind blacklist 5

3.2 Vector differences 5

3.3 Probability density 6

3.4 O vs B speed, direction, u- and v-components 7

3.5 Observation errors and QC checks 8

3.6 GOES reassigned height winds 10

3.7 Meteosat-6 10

3.8 Blacklisted regions 10

4 Recommendations 11

5 Reference 12

1 Current status of satellite wind production

The status of the different satellite wind products is continually changing, due to new satellite launches, production of 'new' types of satellite wind, or changes in the production methods and software used in their derivation. Changes in the recent past and some future developments include:

- The changeover of wind production from ESOC to EUMETSAT (November 1995) resulted in disruption of the winds being disseminated. All satellite winds were severely affected, with a distinct drop in the quality and the number of winds being produced, ostensibly due to a change in algorithm, including stricter quality control (QC)
- EUMETSAT began dissemination of high-resolution VIS winds in BUFR form on the GTS in September 1996

- EUMETSAT extended the processing area of satellite winds to 60 ° from sub-satellite point in January 1997
- Meteosat-6 took over from Meteosat-5 on 13 February 1997
- Meteosat-7 due for launch in July 1997
- EUMETSAT plan to investigate improvements to the semi-transparency correction procedure to improve the wind coverage over subtropical regions with hot surfaces and cirrus
- EUMETSAT intend to distribute clear-air WV winds on the GTS in BUFR format in 1997
- EUMETSAT intend to distribute the full wind product from all three channels in BUFR form with quality indicators in 1997
- EUMETSAT plan to produce winds every 90 min after the launch of Meteosat Second Generation (currently planned for launch in 2000), possibly with tighter QC thresholds at asynoptic times
- GOES-8 became operational on 18 December 1995
- GOES-7 went out of operation on 11 January 1996
- GOES-9 became operational on 26 January 1996
- GOES-K due for launch in April 1997
- NESDIS changed their wind post-production software in April 1996, which led to an increased number of GOES winds on the GTS
- NESDIS hope to start producing satellite winds every 3 h in the near future
- NESDIS intend to start supplying high-resolution satellite winds from summer 1997; these are winds produced from a smaller sampling area not from increased resolution imagery
- 'New' INSAT winds arrived on the GTS in December 1996. They are rumoured to be VIS winds but are appearing at all levels; investigations ongoing

The European and the American geostationary satellite operators generally provide information, such as that given above, to the satellite-wind users. Timely information is harder to come by from the Japanese and the Indian satellite operators. In the near future, satellite winds from the Chinese and the Russians should also be available.

2 Current coverage of satellite winds

Figure 1 shows the global horizontal coverage of all satellites merged together for a 1-week period (22–31 December 1996).

Figure 2 shows the coverage for each individual satellite, indicating the area covered by and the horizontal discretisation of the wind products from each of the geostationary satellites. GOES, GMS and INSAT produce satellite winds on a lat–lon grid, while Meteosat samples in multiples of pixels, producing a resolution of approximately 150 km at sub-satellite point. GMS and Meteosat calculate satellite winds for a full disk image, whereas INSAT concentrates more on the area around the Indian Ocean. The gaps in the GOES satellites' sampling areas result from the requirement to scan the USA at frequent intervals.

Figure 3 shows the vertical coverage of each different satellite and channel combination for 22–31 December 1996. Figure 3 illustrates the vertical discretisation of the different satellites, including the vertical extent over which each different channel is able to 'see' particular tracers. Meteosat and GOES winds are variable in height assignment, i.e. the wind producers consider they have a skill in assigning the height. All INSAT winds and low-level GMS IR and VIS winds are fixed in height.

3 Current quality of satellite winds

Satellite operators usually indicate the quality of their derived satellite winds by comparing them with collocated radiosondes. An alternative method is to compare the derived vectors with a short-range forecast field. In the following figures and discussion, the satellite winds received on the GTS in SATOB format in December 1996 were compared with a Unified Model (UM) global background field. This standardises the quality marks for the different satellites, by comparing them against a consistent background. Of course, this does not take into account the relative quality of the background field for different areas of the globe and vertical levels. In the figures that follow, it must be borne in mind that the statistics indicated for bias, standard deviation and vector difference also include an element of error for the background field.

The figures that follow indicate the satellite and channel, the pressure level, the latitude band and the sampling of satellite winds. For example:

- 'all data' indicates that all the winds received for that satellite/channel combination are included in the statistics
- 'flagged data' means the winds that were not assimilated into the UM, either due to failing QC checks, or being in a blacklisted region
- 'unflagged data' indicates the winds that were assimilated into the UM
- 'background-flagged data' indicates those winds that had a probability of gross error (PGE), after the background QC check, of greater than 0.5 — these may

or may not have been assimilated into the UM, depending on the result of the subsequent buddy check; these winds are suspect

- 'non-background-flagged data' indicates those winds that had a PGE of less than 0.5 after the background QC check — these may or may not have been assimilated into the UM, depending on the result of the subsequent buddy check check
- 'blacklisted data' are those that fall into a blacklisted region
- 'non-blacklisted data' are those that fall outside a blacklisted region

3.1 UKMO satellite wind blacklist

Monitoring statistics are routinely calculated for three different levels: high (1–400 hPa), medium (401–700 hPa) and low (701–1000 hPa). The figures that follow display data for each of the satellite/channel combinations at these levels. The current satellite wind blacklist operates at two levels: 0–500, 501–1000 hPa (Table 1); the most recent operational blacklist change took place on 2 July 1996. A three-level blacklist (Table 2) is therefore proposed to replace the two-level blacklist in order to make a better comparison between monitoring statistics and use of satellite winds in the UM. This would allow better vertical discrimination of wind quality. For example, Meteosat WV winds are generally produced only above 400 hPa, but sometimes winds from lower heights are disseminated. Blacklisting the medium-level WV winds ensures that these (worse quality) winds are not assimilated. Table 2 also gives a clearer indication of the areas and regions for which no data at all are produced ("ND"), although these would be blacklisted regions. The format of Tables 1 and 2 has been designed to make clear which winds are produced in which regions, and whether they are allowed into the UM, and should permit easy understanding of operational changes.

Table 2 is a copy of the current blacklisting situation, expanded to medium levels. Although the current two-level situation would lead to blacklisting in medium levels (due to the overlap), no blacklisting is marked in Table 2 for IR satellite wind types that are already assimilated. See section 3.8 for a further investigation into blacklisted regions.

3.2 Vector differences

Figure 4 shows global vector plots (5 × 5 degree grid boxes) for all IR channels for the three different monitoring levels. All data received on the GTS at the UKMO in December 1996 are included in the plots. Each figure displays observation–background vectors (top), background vectors (middle) and observation vectors (bottom). All observations in a grid box are averaged for the background and observation vector plots, but a vector is only drawn in the O–B plot if there are at least five observations made in that grid box in that particular month. This enables one to see the

likelihood of, for example in Fig. 4(c), low-level IR winds being retrieved over land for a particular satellite. The value of the strongest wind is given in the title of each plot. Note that the scales of the wind arrows are different on the different plots. (A key wind is shown in each case.)

Figure 5 shows global vector plots for WV winds at the two highest levels.

Figure 6 shows global vector plots for VIS winds at the lowest levels.

By inspecting the O–B vector difference plots in Figs 4–6, problem regions can easily be seen, and any land/sea variations should become obvious. These are useful for examining the blacklisting situation with regard to land/sea. Currently, all low-level winds are blacklisted over land (see Table 1). From Figs 4(c) and 6 it can be inferred that few winds are actually retrieved over land at low levels, with the exception of INSAT, as the O–B plot shows hardly any vectors. Inspection of the observation and background plots do indicate that the sporadic ones that are derived are not of very good quality. However, the largest O–B vectors at low levels are to be seen at the eastern edges of the oceans in the southern tropics. These show large monthly averaged vector differences, yet are not blacklisted; they take their chances under QC. See section 3.8 for further discussion of blacklisted regions.

3.3 Probability density

Probability density plots for each type of satellite wind were produced to display O–B speed, O–B direction, O–B u-component of wind speed and O–B v-component of wind speed. Statistics were found for the number of observations evaluated, the O–B bias over the range for the particular set of data, and the O–B standard deviation. For wind direction, data points that had an average observation and background speed of less than 5 m/s were excluded from the statistics, since wind direction under low-speed conditions is more prone to variability. A Gaussian curve was fitted to the data using PV-Wave's GAUSSFIT function. The error characteristics for all the satellite channels were very nearly Gaussian, with no obvious gross error.

Figures 7–9 show sample plots of probability density for: Meteosat IR medium level, GOES-9 WV medium level and INSAT IR medium level, respectively.

Bias and SD statistics for all satellite wind types at the different levels are given in Tables 3–5. Regions where the magnitude of the speed or component bias is greater than 0.5 m/s are given in bold in these tables. These are summarised here:

High level

- Meteosat IR speed (-0.7 m/s), u-component (-1.0 m/s)
- GOES-9 WV speed (1.0 m/s), u-component (0.6 m/s)
- GOES-8 WV speed (0.7 m/s)
- GMS WV u-component (0.7 m/s)

- INSAT IR speed (1.3 m/s)

Medium level

- Meteosat IR speed (-0.6 m/s), u-component (-1.3 m/s)
- GOES-9 IR u-component (-0.9 m/s)
- GOES-9 WV speed (-0.6 m/s), u-component (-1.5 m/s)
- GOES-8 IR speed (0.5 m/s), u-component (-1.3 m/s), v-component (0.5 m/s)
- GOES-8 WV speed (-1.1 m/s), u-component (-1.8 m/s)
- GMS WV speed (1.1 m/s), u-component (0.7 m/s)
- INSAT IR speed (3.3 m/s), u-component (-1.5 m/s)

Low level

- GOES-9 IR u-component (0.5 m/s)
- GMS VIS speed (0.6 m/s)
- INSAT IR speed (2.1 m/s), u-component (-1.4 m/s), v-component (0.5 m/s)

It can be seen from the above that medium-level winds are generally of worse quality than high- or low-level winds

3.4 O vs B speed, direction, u- and v-components

Figures 10–12 are sample scatter plots of observation vs background data for: Meteosat IR high and low level, GOES-9 IR high level and GOES-8 IR low level, respectively. Four plots are displayed in each figure, corresponding to O vs B speed, O vs B direction (the compass bearing is plotted, with 0°being a northerly wind and 90° being an easterly), O vs B u-component of wind speed and O vs B v-component of wind speed. For wind direction, data points that had an average observation and background speed of less than 5 m/s were excluded from the statistics. The O=B line is overplotted, and statistics given which correspond to the O–B bias and the O–B standard deviation, with the number of observations also marked. For the wind speed plots, the average wind speed is calculated. Each point corresponds to a satellite wind reported on the GTS, with a cross indicating a satellite wind that was assimilated into the UM, and a diamond indicating one that was not.

Data for wind speed and wind speed components display the expected scatter about the O=B line, with outliers clearly visible. Data for wind direction display both the discretisation of the satellite wind data (Meteosat every 10°, others every 5°) as well as a certain tendency for winds to be predominantly easterly or westerly,

corresponding to the general zonal circulation. It must be noted that in the case of the direction plots, satellite winds that display, for example, a nearly 360° bearing, can be 'wrapped back' to nearly 0°.

Figure 10(b) displays a set of bad data for Meteosat IR at low levels (observed wind speed much greater than background wind speed, caused by very high-speed westerly components where the background is expecting low-speed easterly components). This tendency was also seen in October and November 1996, and January 1997. Liaison is underway with EUMETSAT to try and identify the reasons for the production of these winds, which are predominantly situated in the tropics and southern hemisphere.

Figure 11 demonstrates the large number of GOES IR winds that are rejected due to the extra height reassignment QC check (see Part II). Many of these winds appear to be within acceptable O–B limits. See section 3.6 for a further analysis of this check.

Although GOES WV winds are derived in both clear and cloudy areas, and the overall statistics reflect this fact, it may be feasible to allow winds produced at the highest levels into the UM, since these winds would almost certainly be measured in cloudy regions. A quality vs height study of GOES WV winds could define a lower limit to be used.

From the wind speed plots, it can be seen whether the wind producers operate a cut-off wind speed. EUMETSAT operate a cut-off at 2.5 m/s for all levels, whereas GOES data show an approximate 2.5 m/s cut off at high and medium levels. INSAT operate a threshold component speed for their IR winds, which was seen in previous months, but this is somewhat blurred by the inclusion of the 'new' winds within the December 1996 dataset. Analysis of the figures (e.g. Fig. 12) show a tendency for winds with zero u- or v-component to be flagged as unacceptable for use in the UM. It is postulated that operating our own low wind speed cut-off would improve the quality of the data presented to the UM.

The statistical information given in the above figures is summarised in Tables 3–5. The well-documented slow bias of satellite winds for high-wind-speed situations is not immediately obvious from these numbers, since the data are averaged for all latitudes. This disguises the slow bias that is generally seen at higher latitudes in the winter season.

In order to give a clearer idea of the number density of satellite winds extracted, contour plots can be produced. Figure 13 shows the observation density of satellite winds at high levels for four different satellite wind types with respect to wind speed.

3.5 Observation errors and QC checks

Observation errors are set by UKMO for quality control assessment (see Part II). The errors set are the error variances in a single u- or v-component. They are derived from monitoring O–B differences, are not synoptically dependent, and assimilation

weights the impact of the observation in proportion to the inverse of the observation error variance.

Table 6 displays biases and standard deviations of the u- and v-components for Meteosat IR for all the layers of interest. Table 7 displays standard deviations of the u- and v-components for three sample layers for some of the satellite wind types available. It can readily be seen that the standard deviations of O–B components differ between u- and v-components at high levels for each satellite, but are similar at low levels; and that the standard deviations differ between satellites.

Table 8 gives the current values for satellite winds at selected pressure levels (Ingleby and Parrett, 1996). The observation errors correspond to the standard deviations derived for Meteosat IR, if one takes a rough average between the two components, since Meteosat statistics were used to derive these errors. However, the difference in standard deviation between the different satellite wind types at one level are almost as large as the observation error difference between pressures of 70 and 1000 hPa (5.0–1.8); observation errors should be refined to take account of this.

Although an asymmetry check exists in QC (for observation speeds less than background speeds), inspection of the figures, e.g. Fig. 10(a), shows the high-speed winds that have been flagged to be considerably adrift of the O=B line. There appears to be some scope for increasing the severity of the asymmetry check, and thus flagging winds that are nearer the O=B line. This would in some part deal with the high-speed slow-bias problem, and decrease any tendency of satellite winds to slow down the model wind speeds.

A further refinement of the current QC system would be to install our own observation low-wind-speed cut off. Table 9 summarises the effect on O–B wind speed bias at different levels for some satellite wind types if a cut off at 5 m/s is put into effect for satellite wind data from 22–31 January 1997. At medium and high levels, the bias generally becomes less negative with the cut off installed, but not significantly, while the standard deviation increases (not shown in table). At low levels, the cut off generally makes the bias more positive, which is not desirable.

Figure 14 displays wind speed statistics at the three different monitoring levels for those satellite wind types that are fully blacklisted at UKMO: INSAT IR, GOES WV and GMS WV. They are divided into non-background-flagged and background-flagged datasets, so that the impact of current QC checks against background can be observed. Figure 14(a,b) shows that only extreme INSAT IR outliers fail the background check, with the overall quality of the winds passing the background check generally poor. Figure 14(b,c) displays GOES-8 WV data; high-level winds display good statistics, especially those that pass the background check. Medium-level winds are of reasonable quality. Figure 14(c) shows that the GMS WV data is of worse quality than GOES-8 WV, with the background check managing to filter out the very bad winds.

ECMWF started to assimilate the GOES WV winds at high levels, along with high-resolution Meteosat VIS winds, at the end of 1996 after impact experiments had been carried out. Assimilation at ECMWF is currently 3-D VAR.

3.6 GOES reassigned height winds

To investigate the quality difference between those GOES winds that have had their height reassigned by NESDIS and subsequently been background-flagged, Fig. 15 displays scatter plots of O vs B wind speed and their statistics for GOES-9 IR and Meteosat IR at the three monitoring levels. It is the height reassignment check that causes most GOES data to be flagged against background at the two highest levels. The top box in Fig. 15(a,b,c) shows GOES-9 non-background-flagged data, the second box background-flagged data, the third box all data, and the bottom box Meteosat IR all data for comparison. The GOES-9 background-flagged data display worse statistics than the non-background-flagged data, however background-flagged GOES-9 winds still show better quality than all Meteosat IR data for the two highest levels. The conclusion is that relaxing or removing the extra QC check on the GOES reassigned winds should have no significant effect on the quality of the data allowed into regular QC at these levels. At the lowest level, however (Fig. 15c), GOES-9 background-flagged data are of considerably worse quality, although it cannot be established whether these winds are background-flagged due to height reassignment.

3.7 Meteosat-6

Table 10 gives an initial indication of the quality of satellite wind data we may expect when Meteosat-6 takes over operations from Meteosat-5. For five days in October 1996, Meteosat-6 replaced -5; the O–B wind speed bias and standard deviation of these data are given in Table 10, along with those of Meteosat-5 for the week prior to this. At the time, Meteosat-6 was situated at 10°W, and the images it sent were rectified to a nominal 0° position. In February 1997, Meteosat-6 will be manoeuvred to 0° and so should produce slightly higher quality wind data. For the weeks illustrated, Meteosat-6 transmitted worse quality data than -5 overall when divided into latitude bands but when averaged over all latitude bands, Meteosat-6 winds did not display statistics that were significantly worse than Meteosat-5 (not shown).

3.8 Blacklisted regions

Figure 16(a,b) shows sample plots of blacklisted and non-blacklisted O vs B wind speed scatter plots for low-level Meteosat IR, and for low-level GOES IR in the northern hemisphere and tropics for December 1996. The figure indicates whether the relevant data point is flagged with respect to the UM background. On the whole, the number of winds reported in the blacklisted regions (i.e. over land) is small compared with the number of winds in non-blacklisted regions, and so the derived statistics are misleading. Whether an observation has been flagged against background gives a clearer comparison between blacklisted and non-blacklisted regions.

Within the individual quality characteristics for each satellite/channel combination, there appears to be no difference in the quality between blacklisted and non-blacklisted

regions, with the possible exception of GOES-8 low-level winds which show more very low wind speed observations. These have mostly been background-flagged, and could be removed if we installed our own low wind speed cut off criterion. There does not seem to be a quality argument for blacklisting regions of satellite wind data.

4 Recommendations

Listed below are recommendations for the improvement of the use of satellite winds within NWP.

- **ITO:** Extract and read into the MetDB all satellite winds transmitted on GTS in both BUFR and SATOB codes
- **ITO, US, DA, SA:** Ensure that all operational procedures can deal with planned increases in volumes of satellite wind data
- **NMC:** NMC intervention of satellite winds should not check the difference between reported satellite wind temperature and background field temperature, since this compares the vertical temperature profile forecast of, for example, ECMWF, with that of UKMO, and is not an indication of the quality of the satellite wind
- **DA(OM):** Change blacklist levels to coincide with those of monitoring statistics
- **DA(OM), with SA:** Reassess the blacklisting procedure, with a view to modifying the current blacklisted datasets
- **DA:** Update initial probability of gross errors in wind speed and location based on recent O–B statistics, and consider taking account of the differences between satellites and channels
- **DA:** Use O–B statistics from recent monitoring to reset the observation errors, taking account of the fact that O–B statistics include background error. There is evidence that some observation errors are set too high. Consider taking account of the differences between satellites and channels
- **DA:** Consider setting different observation errors for u- and v-components (given that u-component generally exceeds v-component for satellite winds)
- **DA:** Consider installing an observation low-wind-speed cut off at high and medium levels
- **DA:** Remove/modify GOES height reassignment penalty
- **SA:** Investigate effects of making asymmetry check as stringent as that at ECMWF (if satellite wind speed less than background speed, penalise even more heavily in QC)

- **SA:** Investigate the quality of GOES WV winds at high levels (assumed to be cloudy regions)
- **SA:** Investigate candidates for impact experiments from satellite wind datasets not currently used and conduct impact experiments
- **SA:** Investigate effects on quality of assigning our own height to the winds using the reported temperature provided with the satellite wind (removes first-order dependence on another model's temperature profile)
- **SA:** Encourage satellite wind producers to keep users informed of all changes to satellite, method, new products, etc., through increased liaison and participation in the activities of the International Wind Workshops
- **SA:** Encourage satellite wind producers to transmit products as raw as possible; if data massaging is to take place then NWP centres would rather tailor it to their own specifications
- **SA:** Provide feedback and suggest improvements to satellite wind producers, through increased liaison and participation in the activities of the International Wind Workshops

5 Reference

Ingleby NB and CA Parrett (1996) Quality control of atmospheric data. UMDP 32, UKMO, Bracknell.

FIGURE CAPTIONS

A full set of figures which correspond to the ones given in this report, but for all satellites over all regions, can be accessed from within the UKMO via:

http://fr1500/~frbp/home.html

Table 1. Current UKMO satellite wind two-level blacklist.

Table 2. Proposed UKMO satellite wind three-level blacklist.

Table 3. Biases and standard deviations for O–B speed, direction and component speeds for the different satellite wind types at high levels, December 1996, all data, all latitudes.

Table 4. Biases and standard deviations for O–B speed, direction and component speeds for the different satellite wind types at medium levels, December 1996, all data, all latitudes.

Table 5. Biases and standard deviations for O–B speed, direction and component speeds for the different satellite wind types at low levels, December 1996, all data, all latitudes.

Table 6. Biases and standard deviations for component speeds for Meteosat IR at varying levels, December 1996, all data, all latitudes.

Table 7. Standard deviations for component speeds for some satellite wind types over three sample layers,December 1996, all data.

Table 8. RMS component wind errors at model levels (Ingleby and Parrett, 1996).

Table 9. O–B wind speed bias (m/s) with no wind speed cut off and a 5 m/s wind speed cut off; different satellite wind types, all data, 22-31 January 1997.

Table 10. Comparison of Meteosat-5 and -6 satellite winds vs UM background field.

Fig. 1. Global coverage of satellite winds, 22–31 December 1996.

Fig. 2. Areas of coverage for each of the different geostationary satellites.

Fig. 3. Vertical satellite wind coverage during 22–31 December 1996 for (a) Meteosat IR, Meteosat WV, Meteosat VIS and INSAT; (b) GOES-9 and -8 IR and WV; (c) GMS IR, GMS VIS and GMS WV.

Fig. 4. Plots of O–B vector differences, observation and background vectors for IR satellite winds, December 1996: (a) 1–400 hPa, (b) 401–700 hPa, (c) 701–1000 hPa.

Fig. 5. Plots of O–B vector differences, observation and background vectors for WV satellite winds, December 1996: (a) 1–400 hPa, (b) 401–700 hPa.

Fig. 6. Plots of O–B vector differences, observation and background vectors for VIS satellite winds, December 1996, 701–1000 hPa.

Fig. 7. Probability density plots of O–B differences in speed, direction, u- and v-components, December 1996: Meteosat IR, 401–700 hPa.

Fig. 8. Probability density plots of O–B differences in speed, direction, u- and v-components, December 1996: GOES-9 WV, 401–700 hPa.

Fig. 9. Probability density plots of O–B differences in speed, direction, u- and v-components, December 1996: INSAT IR, 401–700 hPa.

Fig. 10. Scatter plots of O vs B speed, direction, u- and v-components, December 1996: (a) Meteosat IR, 1–400 hPa; (b) Meteosat IR, 701–1000 hPa.

Fig. 11. Scatter plots of O vs B speed, direction, u- and v-components, December 1996: GOES-9 IR, 1–400 hPa.

Fig. 12. Scatter plots of O vs B speed, direction, u- and v-components, December 1996: GOES-8 IR, 701-1000 hPa.

Fig. 13. Example contour plots of O vs B speed, December 1996: Meteosat IR, GOES-9 IR, GMS IR, Meteosat WV, 1–400 hPa, northern hemisphere.

Fig. 14. Fully blacklisted data types; difference between non-background-flagged and background-flagged data: (a) INSAT IR, 1–400, 401–700 hPa; (b) INSAT IR, 701–1000 hPa; GOES-8 WV, 1–400 hPa; (c)GOES-8 WV, 401–700 hPa; GMS WV, 1–400 hPa.

Fig. 15. Scatter plots of O vs B wind speed to investigate GOES height reassignment: GOES-9 IR, non-background-flagged data, background-flagged data, all data; Meteosat IR, all data, 22–31 January 1997: (a) 1–400 hPa; (b) 401–700 hPa; (c) 701–1000 hPa.

Fig. 16. Scatter plots of O vs B wind speed for non-blacklisted and blacklisted data at low and medium levels (LL, ML) for different satellite winds, 1–31 December 1996, distinguishing between background-flagged and non-background-flagged data: (a) Meteosat LL IR, NH, TR; (b) GOES-8 LL IR, NH, TR.

Table 1.
UK MET OFFICE BLACKLISTED SATELLITE WIND DATA; 2/7/96 change
X=blacklisted

		MET_IR		GOES8_IR		GOES9_IR		GMS_IR		INSAT_IR	
		HL	LL	HL	LL	HL	LL	HL	LL	HL	LL
NH	LAND		X		X		X		X	X	X
	SEA									X	X
TR	LAND		X		X		X		X	X	X
	SEA									X	X
SH	LAND		X		X		X		X	X	X
	SEA									X	X

		MET_WV (cloudy)+		GOES8_WV		GOES9_WV		GMS_WV	
		HL	LL*	HL	LL	HL	LL	HL	LL
NH	LAND			X	X	X	X	X	X
	SEA			X	X	X	X	X	X
TR	LAND			X	X	X	X	X	X
	SEA			X	X	X	X	X	X
SH	LAND			X	X	X	X	X	X
	SEA			X	X	X	X	X	X

		MET_VIS(half-res)		MET_VIS(full-res)#		GMS_VIS	
		HL*	LL	HL	LL	HL	LL
NH	LAND	X	X	X	X	X	X
	SEA			X	X		
TR	LAND	X	X	X	X	X	
	SEA			X	X		
SH	LAND	X	X	X	X	X	X
	SEA			X	X		

Notes: NH=north of 20 N, TR=20 N - 20 S, SH=south of 20 S; HL= 0 - 500 hPa, LL= 501 - 1000 hPa; LAND, SEA= over land or sea, respectively; *=no such data normally available; #=not in satob code; +Meteosat clear-air WV winds not used in model, not in satob code.

v3a/30/1/97

Table 2.
UK MET OFFICE BLACKLISTED SATOB DATA (proposed; 3 levels)
X/ND=blacklisted

		MET_IR			GOES8_IR			GOES9_IR			GMS_IR			INSAT_IR		
		HL	ML	LL	HL	ML	LL	HL	ML	LL	HL	ML	LL	HL	ML	LL
NH	LAND			X			X			X		ND	X	X	X	X
	SEA											ND		X	X	X
TR	LAND			X			X			X		ND	X	X	X	X
	SEA											ND		X	X	X
SH	LAND			X			X			X		ND	X	X	X	X
	SEA											ND		X	X	X

		MET_WV (cloudy)			MET_WV (clear)#			GOES8_WV			GOES9_WV			GMS_WV		
		HL	ML	LL	HL	ML	LL	HL	ML	LL	HL	ML	LL	HL	ML	LL
NH	LAND		ND	ND	X	X	ND	X	X	ND	X	X	ND	X	X	ND
	SEA		ND	ND	X	X	ND	X	X	ND	X	X	ND	X	X	ND
TR	LAND		ND	ND	X	X	ND	X	X	ND	X	X	ND	X	X	ND
	SEA		ND	ND	X	X	ND	X	X	ND	X	X	ND	X	X	ND
SH	LAND		ND	ND	X	X	ND	X	X	ND	X	X	ND	X	X	ND
	SEA		ND	ND	X	X	ND	X	X	ND	X	X	ND	X	X	ND

		MET_VIS(half)			MET_VIS(full)#			GMS_VIS		
		HL	ML	LL	HL	ML	LL	HL	ML	LL
NH	LAND	ND	ND	X	ND	ND	X	ND	ND	X
	SEA	ND	ND		ND	ND	X	ND	ND	
TR	LAND	ND	ND	X	ND	ND	X	ND	ND	X
	SEA	ND	ND		ND	ND	X	ND	ND	
SH	LAND	ND	ND	X	ND	ND	X	ND	ND	X
	SEA	ND	ND		ND	ND	X	ND	ND	

Notes: NH=north of 20N, TR=20N - 20S, SH=south of 20S; HL=0-400 hPa, ML=401-700 hPa, LL=701-1000 hPa; LAND, SEA=over land or sea, respectively; X=blacklisted; ND=no such data normally available but blacklisted; #=only available in BUFR on GTS.
v4/5/2/97

Table 3. Biases and standard deviations for O-B speed, direction and component speeds for the different satellite wind types at high levels, December 1996, all data

Satellite		Meteosat IR	Meteosat WV	GOES-9 IR	GOES-9 WV	GOES-8 IR	GOES-8 WV	GMS IR	GMS WV	INSAT IR
HIGH LEVEL										
No. of obs		11750	41359	27415	75515	25196	86967	19169	16856	5999
Ave speed (m/s):		24.2	24.7	19.2	16.7	18.2	18.5	19.2	15.1	11.7
O-B speed	Bias (m/s)	**-0.7**	0.1	0.0	**1.0**	0.1	**0.7**	0.2	0.4	**1.3**
	SD (m/s)	5.2	5.4	3.8	3.9	3.7	4.1	5.5	6.0	5.5
O-B direction	Bias (°)	0.3	0.3	0.5	-0.1	0.3	0.5	1.2	1.7	-1.8
	SD (°)	15.8	14.9	16.8	19.2	18.4	19.4	22.9	28.9	29.7
O-B u-compt	Bias (m/s)	**-1.0**	-0.4	-0.2	**0.6**	-0.3	0.1	0.2	**0.7**	-0.2
	SD (m/s)	5.2	5.3	3.9	4.1	3.9	4.2	5.5	6.0	6.1
O-B v-compt	Bias (m/s)	-0.3	-0.2	0.0	0.3	-0.1	-0.1	0.2	0.2	0.1
	SD (m/s)	4.9	4.8	4.0	4.1	3.8	4.2	5.1	5.2	5.0

Table 4. Biases and standard deviations for O-B speed, direction and component speeds for the different satellite wind types at medium levels, December 1996, all data

Satellite:		Meteosat IR	GOES-9 IR	GOES-9 WV	GOES-8 IR	GOES-8 WV	GMS WV	INSAT IR
MEDIUM LEVEL								
No. of obs:		4880	10267	4962	11852	8925	3202	6423
Ave speed (m/s):		15.0	12.9	11.3	11.1	13.6	18.9	10.1
O-B speed	Bias (m/s)	**-0.6**	0.1	**-0.6**	**0.5**	**-1.1**	**1.1**	**3.3**
	SD (m/s)	4.2	2.9	3.7	2.9	3.9	7.2	5.6
O-B direction	Bias (°)	-1.5	-1.3	-0.2	1.6	0.4	-0.7	-1.1
	SD (°)	17.1	17.7	25.6	20.1	23.0	27.0	35.3
O-B u-compt	Bias (m/s)	**-1.3**	**-0.9**	**-1.5**	**-1.3**	**-1.8**	**0.7**	**-1.5**
	SD (m/s)	4.1	2.9	3.9	2.9	3.7	7.4	6.7
O-B v-compt	Bias (m/s)	-0.2	-0.2	0.1	**0.5**	0.2	0.4	0.2
	SD (m/s)	3.5	3.0	3.8	3.0	4.0	5.4	5.1

Table 5. Biases and standard deviations for O-B speed, direction and component speeds for the different satellite wind types at low levels, December 1996, all data

Satellite:		Meteosat IR	Meteosat VIS	GOES-9 IR	GOES-8 IR	GMS IR	GMS VIS	INSAT IR
LOW LEVEL								
No. of obs:		23232	13436	35211	30306	27461	23780	16511
Ave speed (m/s):		8.9	7.7	9.8	8.6	9.0	9.5	7.7
O-B speed	Bias (m/s)	0.1	0.3	-0.2	0.1	0.2	**0.6**	**2.1**
	SD (m/s)	2.4	2.0	2.4	2.9	2.3	2.2	3.9
O-B direction	Bias (°)	0.3	1.2	-1.2	-0.3	-0.2	-0.3	1.8
	SD (°)	15.1	14.6	15.7	16.9	15.3	14.0	27.2
O-B u-compt	Bias (m/s)	0.1	-0.3	**0.5**	0.1	0.3	-0.3	**-1.4**
	SD (m/s)	2.6	1.9	2.4	2.8	2.4	2.2	4.4
O-B v-compt	Bias (m/s)	0.1	0.3	-0.1	0.2	0.0	-0.1	**0.5**
	SD (m/s)	2.2	2.2	2.5	2.7	2.3	2.4	3.7

Table 6. Biases and standard deviations for component speeds for Meteosat IR at varying levels, December 1996, all data

Level (hPa):		0-274	275-349	350-449	450-599	600-774	775-924
O-B u-compt	Bias (m/s)	-0.6	-1.6	-1.4	-1.1	-1.1	0.2
	SD (m/s)	5.1	5.4	5.0	4.2	3.5	2.4
O-B v-compt	Bias (m/s)	-0.3	-0.3	0.0	-0.2	0.3	0.1
	SD (m/s)	5.0	4.9	4.1	3.7	2.9	2.1

Table 7. Standard deviations for component speeds for some satellite wind types over three sample layers; December 1996, all data

Layer (hPa)	O-B SD (m/s)	Meteosat IR	Meteosat WV	Meteosat VIS	GOES-9 IR	GMS IR	GMS VIS	INSAT
0-274	u-compt	5.1	5.0	-	4.0	5.1	-	6.1
	v-compt	5.0	4.7	-	4.1	5.1	-	4.9
350-449	u-compt	5.0	6.0	-	3.6	6.1	-	6.3
	v-compt	4.1	5.3	-	3.7	4.9	-	5.2
775-924	u-compt	2.4	-	1.8	2.4	2.4	2.2	4.4
	v-compt	2.1	-	2.1	2.5	2.3	2.4	3.7

Table 8. RMS component wind errors at model levels (Ingleby and Parrett, 1996)

Pressure (hPa)	70	100	150	200	250	300	400	500	700	850	1000
RMS conpt wind errors (m/s)	5.0	5.0	5.0	5.0	5.0	4.6	4.0	2.1	1.9	1.8	1.8

Table 9. O-B wind speed bias (m/s) with no wind speed cut off and a 5 m/s wind speed cut off; different satellite wind types, all data, 22-31 January 1997

		Meteosat IR	Meteosat WV	Meteosat VIS	GOES-9 IR	GOES-9 WV	GMS IR
High level	No cut off	-0.4	0.2	-	-0.2	-	-0.2
	5 m/s cut off	-0.3	0.2	-	-0.1	-	-0.2
Medium level	No cut off	-0.5	-	-	0.3	-0.1	-
	5 m/s cut off	-0.4	-	-	0.3	0.0	-
Low level	No cut off	0.1	-	0.5	-0.1	-	0.5
	5 m/s cut off	0.2	-	0.6	0.1	-	0.8

Table 10. Comparison of Meteosat-5 and -6 satellite winds vs UM background field

Meteosat-5: data received 14-21 October 1996
Meteosat-6: data received 22-25 October 1996

Wind type	Level (hPa)	Latitude	No. of obs	No. bkgnd flagged	Speed bias (m/s)	Speed SD (m/s)
IR	1-400	NH	607 **153**	7 **5**	-1.2 **-1.7**	4.8 **5.0**
		TR	694 **447**	1 **0**	0.8 **1.3**	4.7 **4.5**
		SH	856 **338**	19 **6**	-2.1 **-1.7**	6.6 **5.5**
	401-700	NH	130 **163**	3 **3**	-1.6 **-3.0**	4.0 **3.3**
		TR	356 **167**	8 **7**	1.4 **2.3**	3.1 **3.6**
		SH	307 **217**	4 **2**	0.1 **0.6**	4.3 **4.0**
	701-1000	NH	661 **294**	0 **1**	-0.1 **-0.3**	2.0 **2.4**
		TR	3335 **1882**	19 **32**	-0.2 **0.8**	2.2 **2.7**
		SH	1136 **727**	5 **4**	-0.3 **-0.4**	2.8 **2.3**
WV	1-400	NH	2124 **908**	15 **10**	-0.8 **-0.3**	4.8 **5.1**
		TR	2013 **1352**	8 **8**	1.5 **2.3**	4.6 **4.6**
		SH	2716 **1392**	30 **27**	-0.6 **-0.5**	6.4 **5.6**
VIS	701-1000	NH	279 **48**	0 **0**	0.8 **0.7**	2.1 **2.9**
		TR	2029 **672**	7 **0**	0.1 **0.7**	2.1 **2.0**
		SH	633 **193**	6 **1**	-0.3 **-0.4**	2.2 **2.3**

NH=north of 20N, TR=20N - 20S, SH=south of 20S
pb/31/1/97

Fig. 1. Global coverage of satellite winds, 22–31 December 1996.

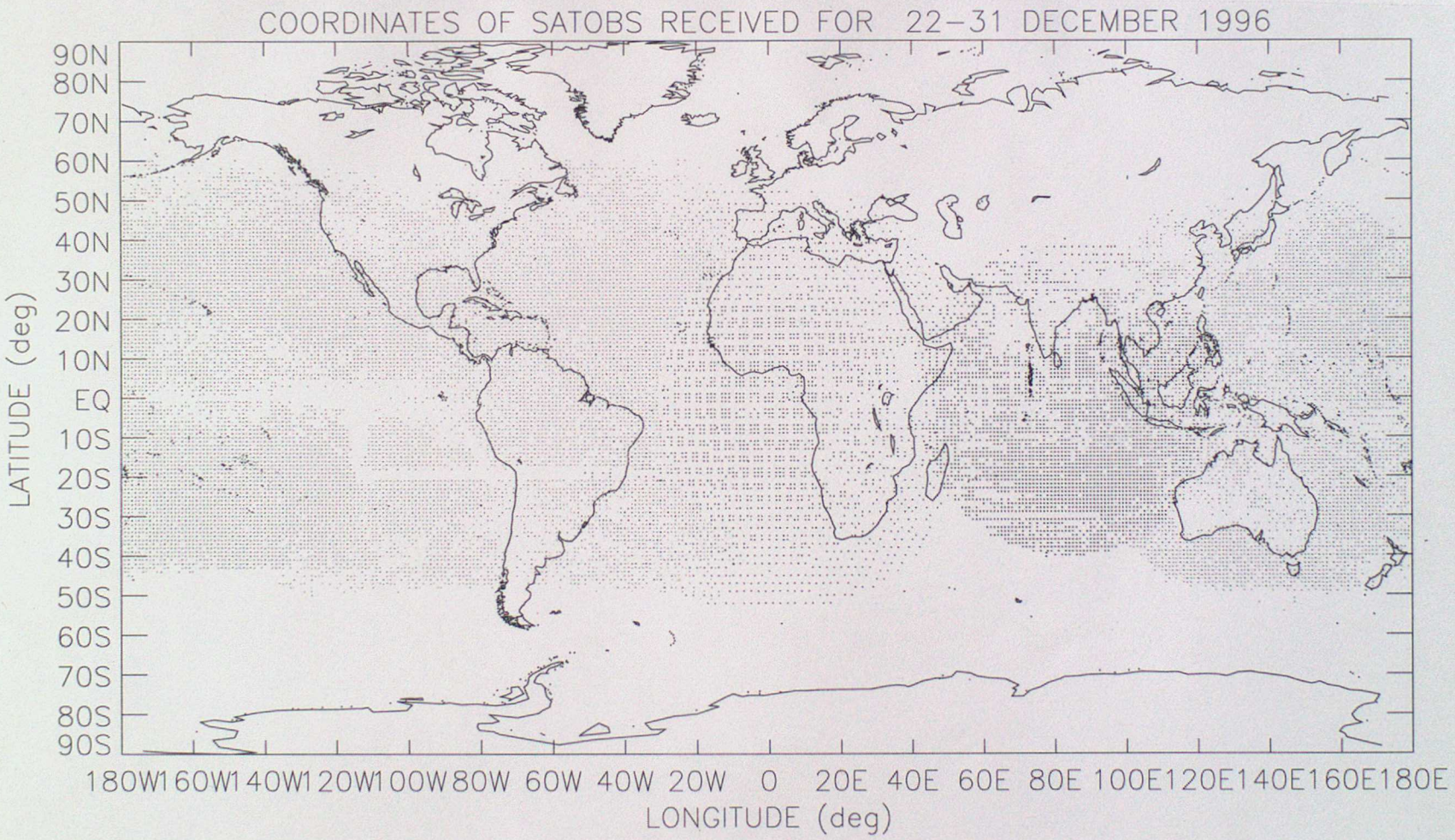


Fig. 2. Areas of coverage for each of the different geostationary satellites.

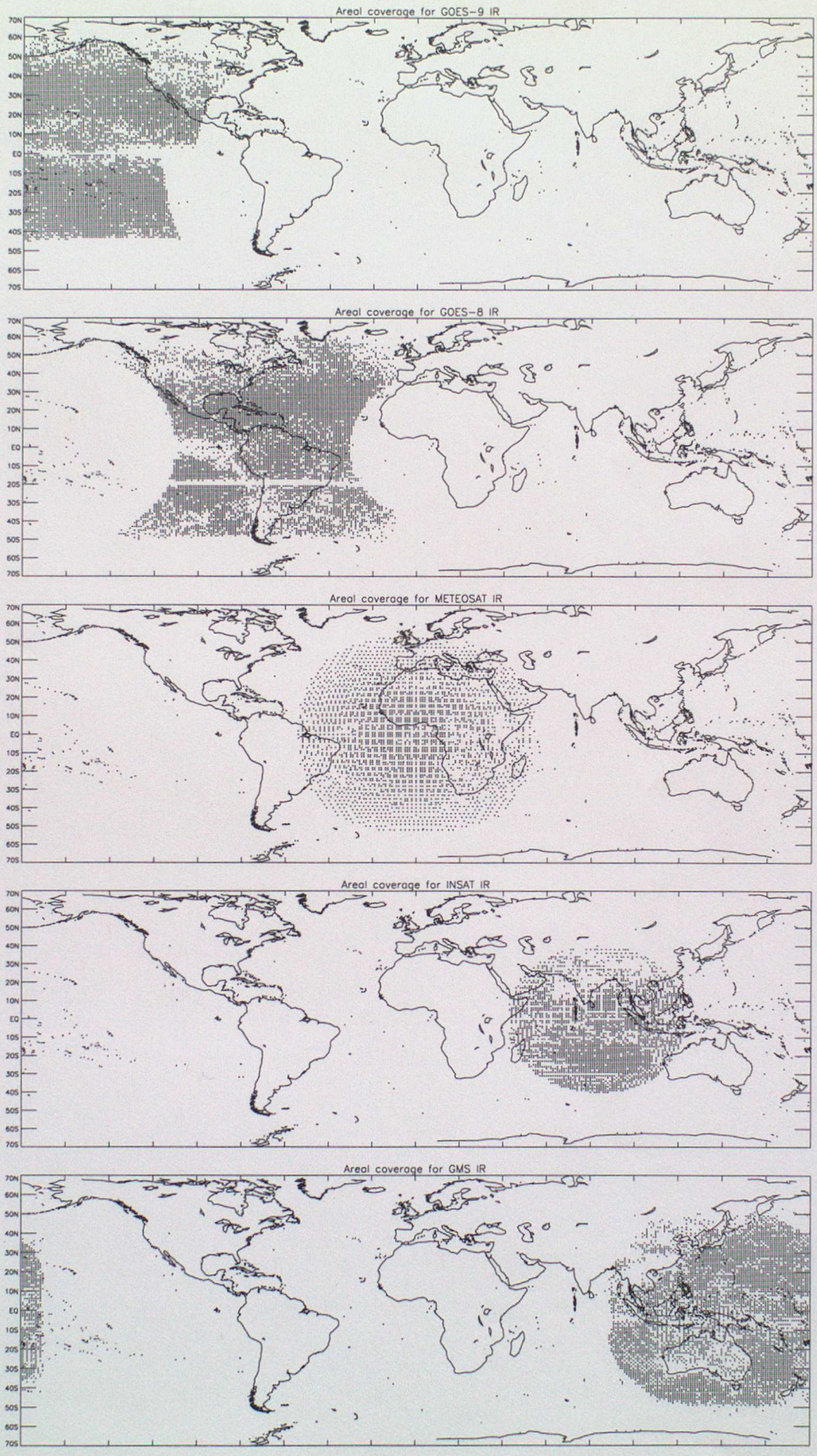


Fig. 3(a). Vertical satellite wind coverage during 22–31 December 1996 for Meteosat IR, Meteosat WV, Meteosat VIS and INSAT.

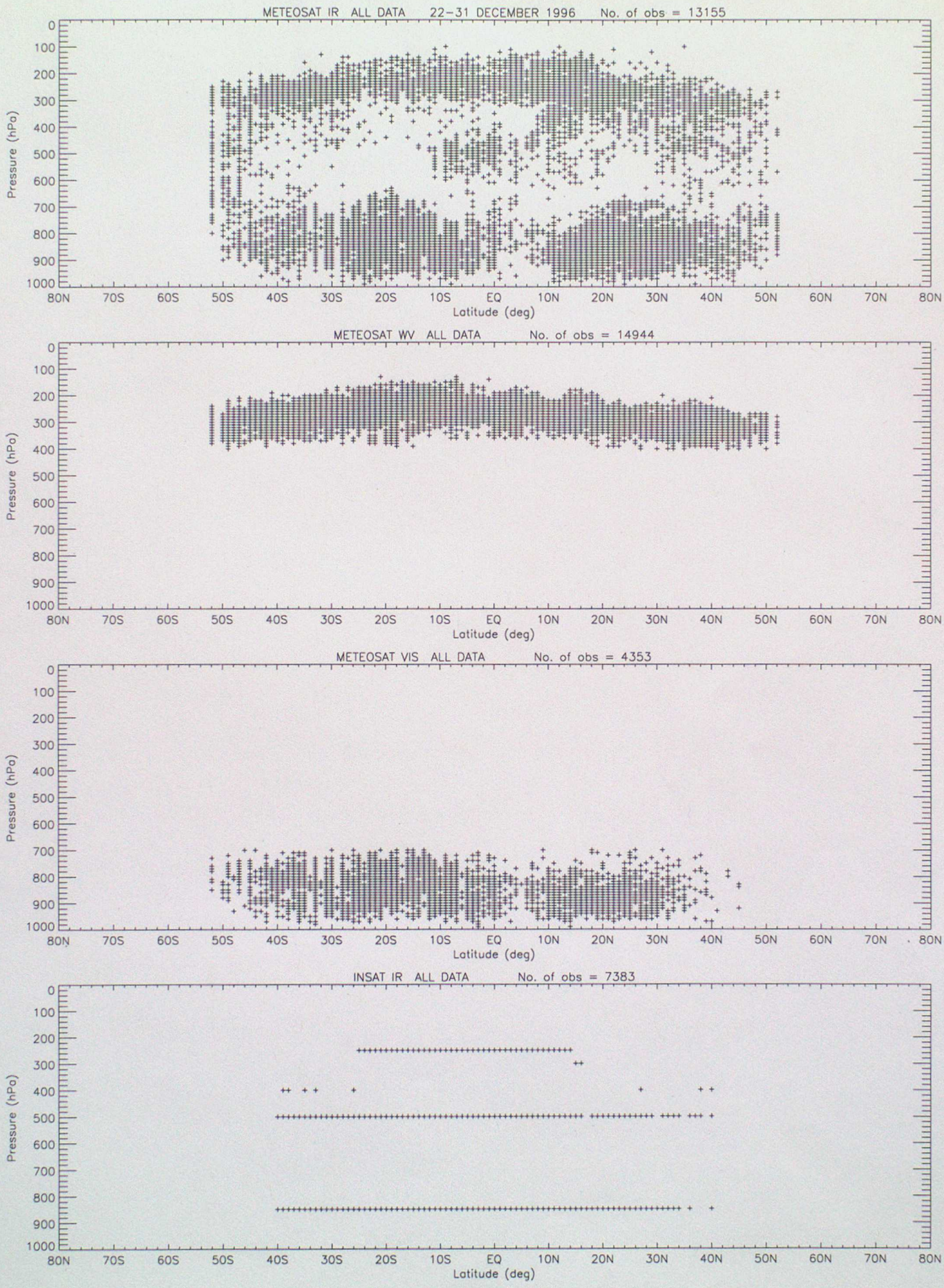


Fig. 3(b). Vertical satellite wind coverage during 22–31 December 1996 for GOES-9 and -8 IR and WV.

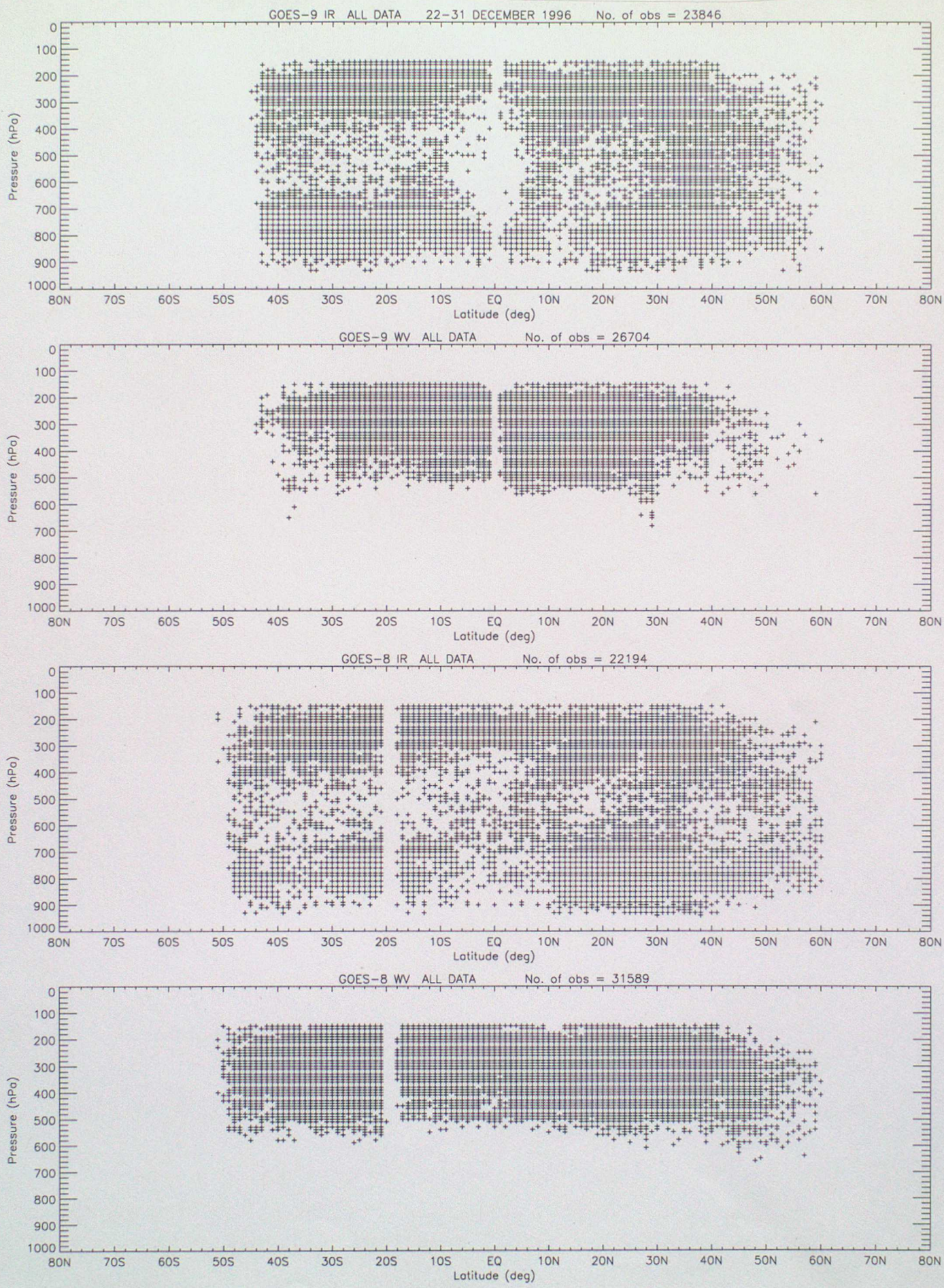


Fig. 3(c). Vertical satellite wind coverage during 22–31 December 1996 for GMS IR, GMS VIS and GMS WV.

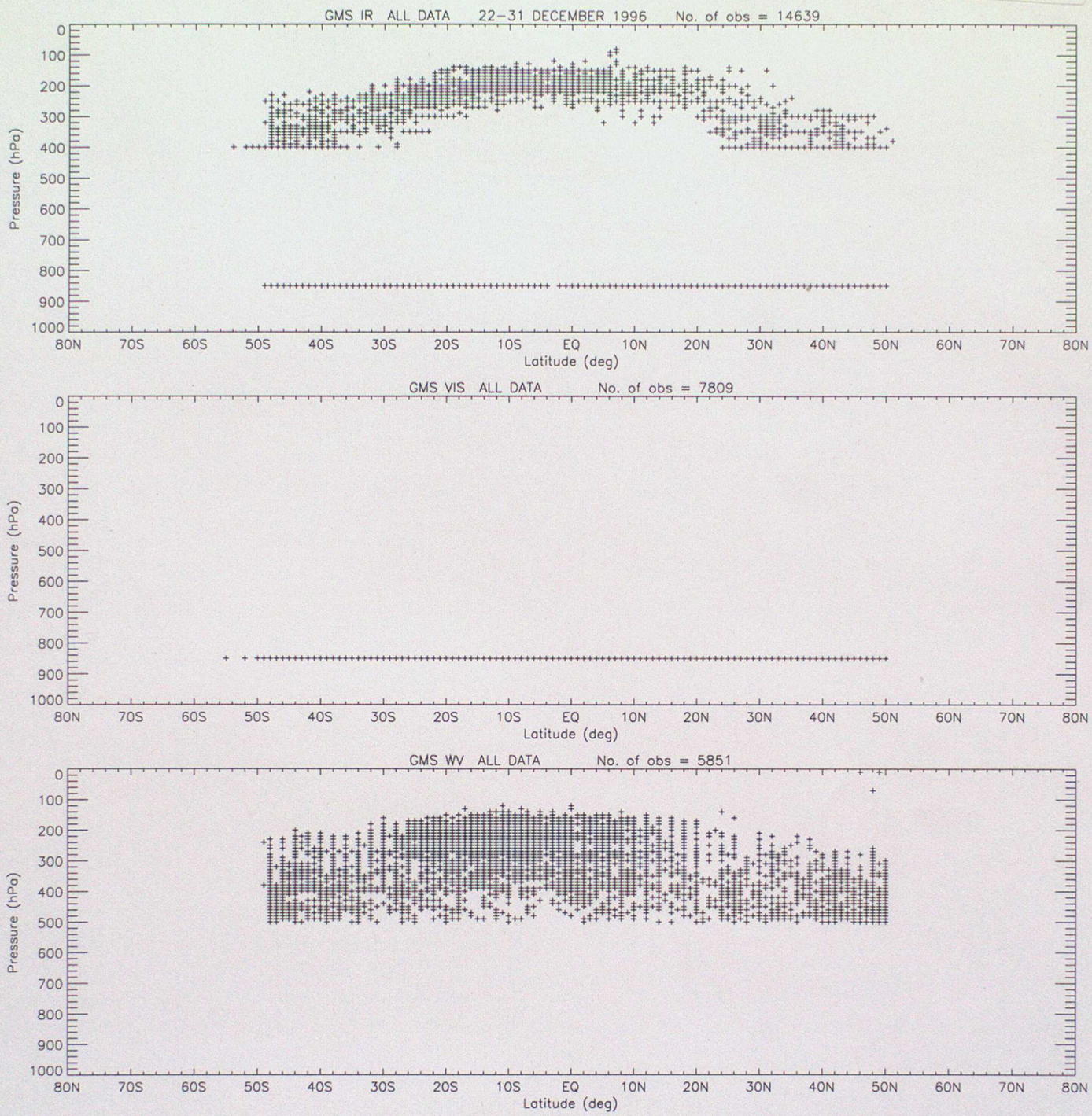
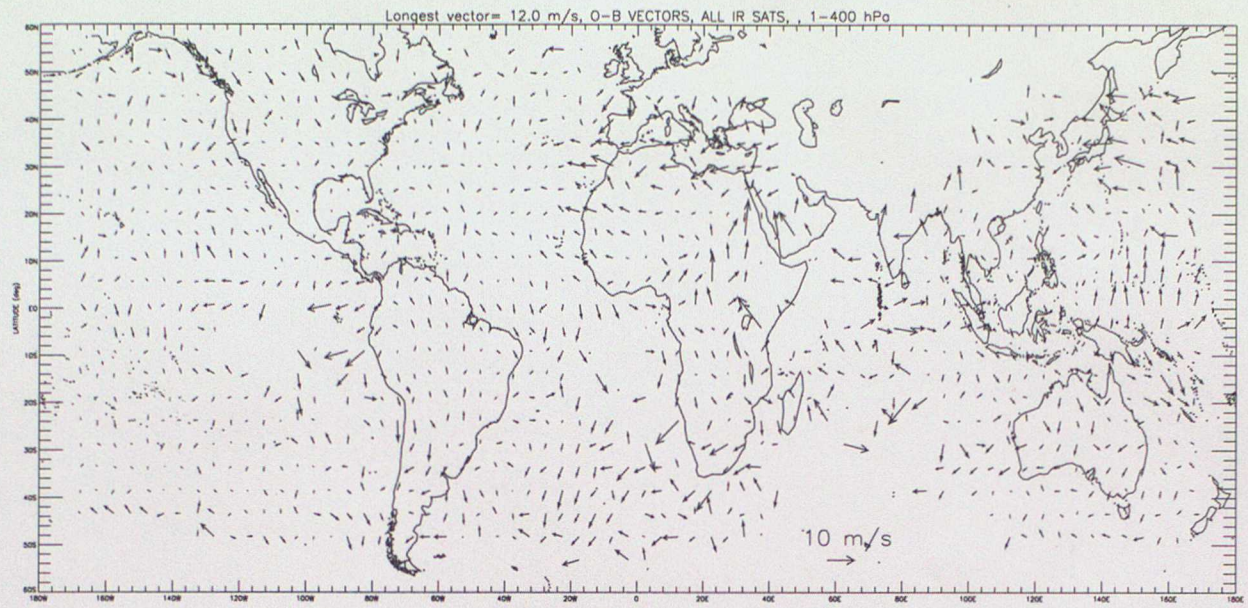
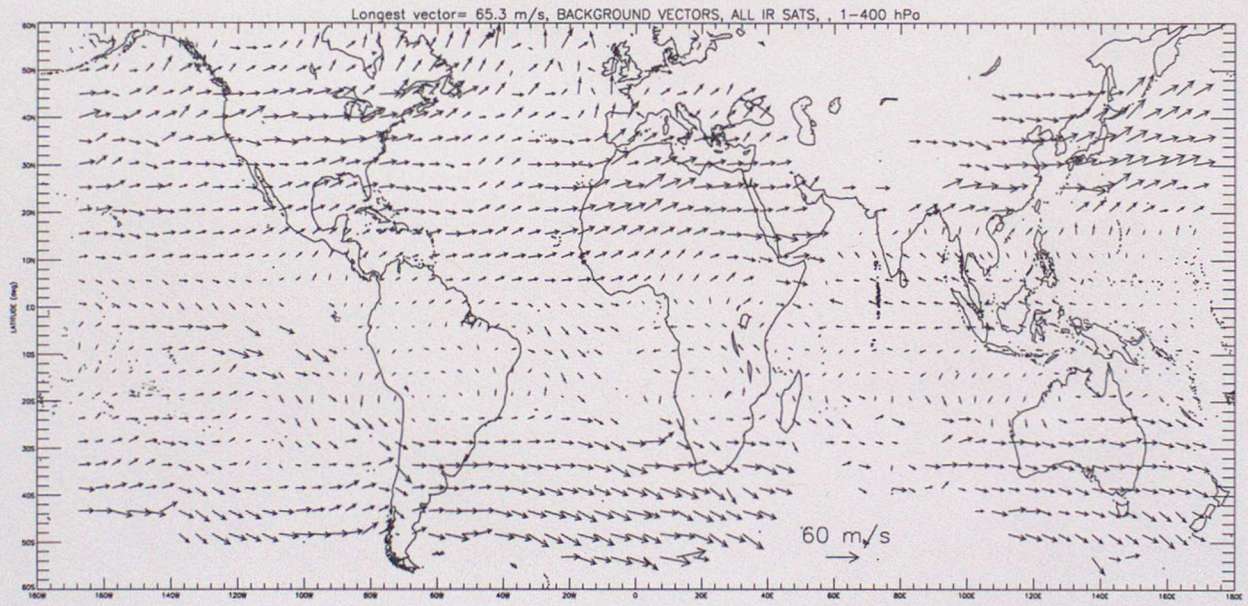


Fig. 4(a). Plots of O–B vector differences, observation and background vectors for IR satellite winds, December 1996: 1–400 hPa.





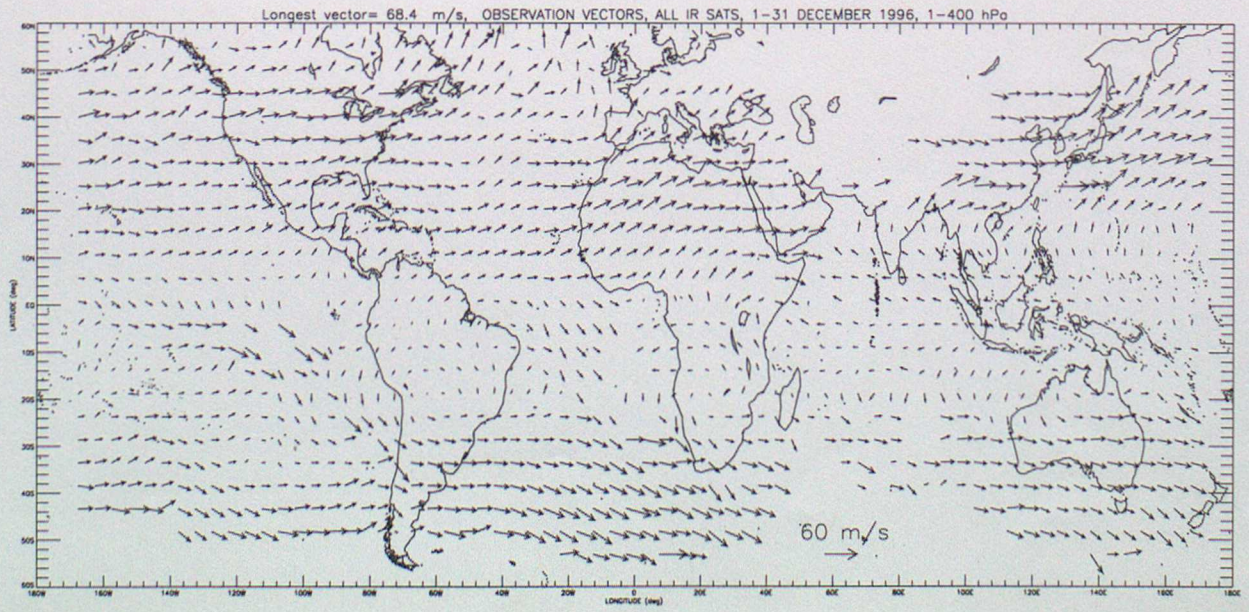
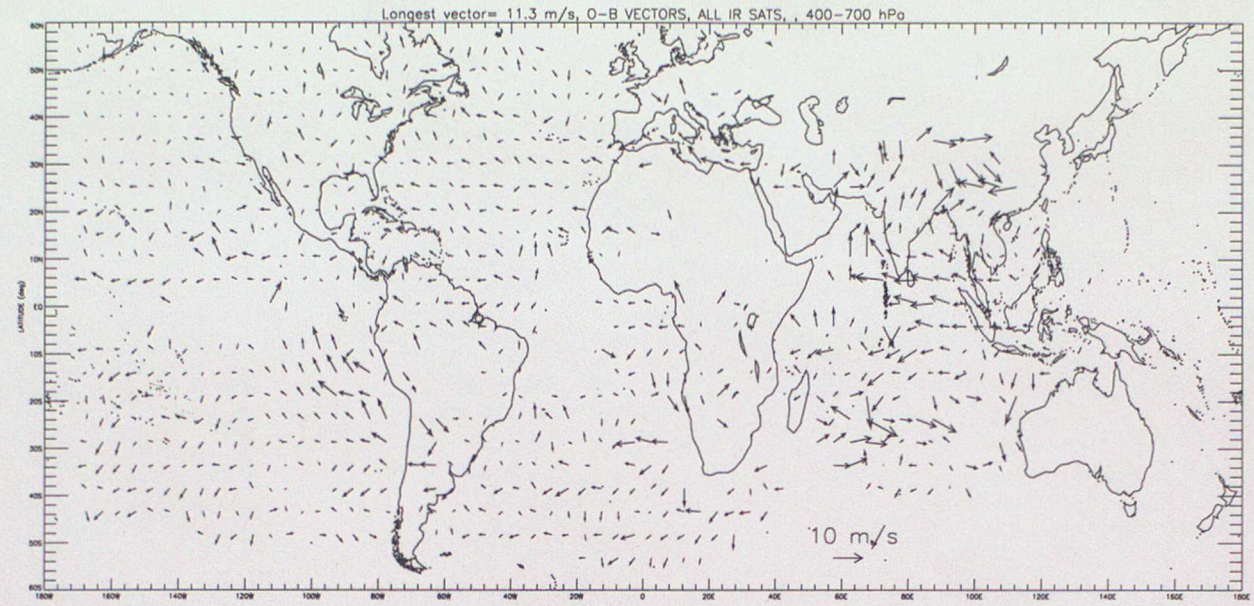
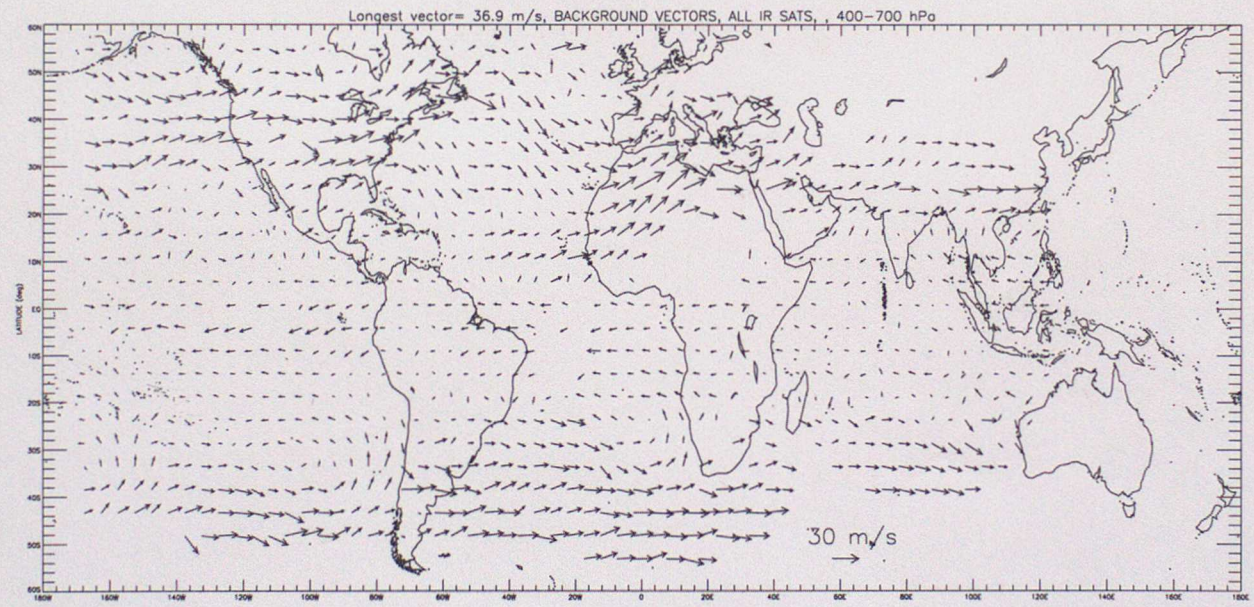


Fig. 4(b). Plots of O–B vector differences, observation and background vectors for IR satellite winds, December 1996: 401–700 hPa.





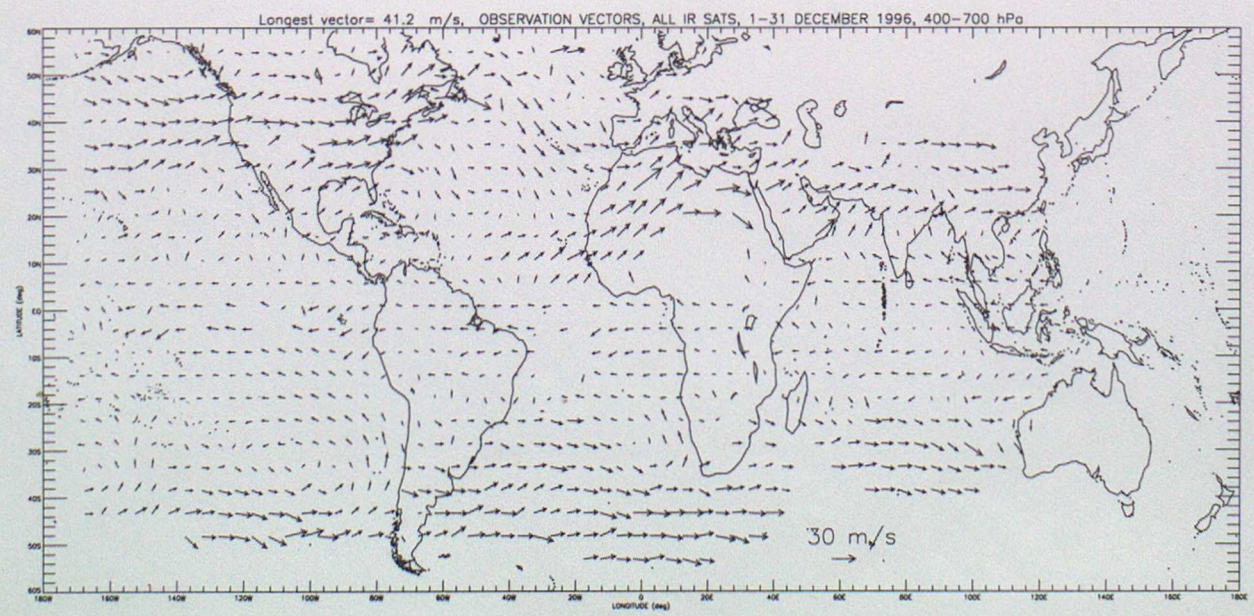
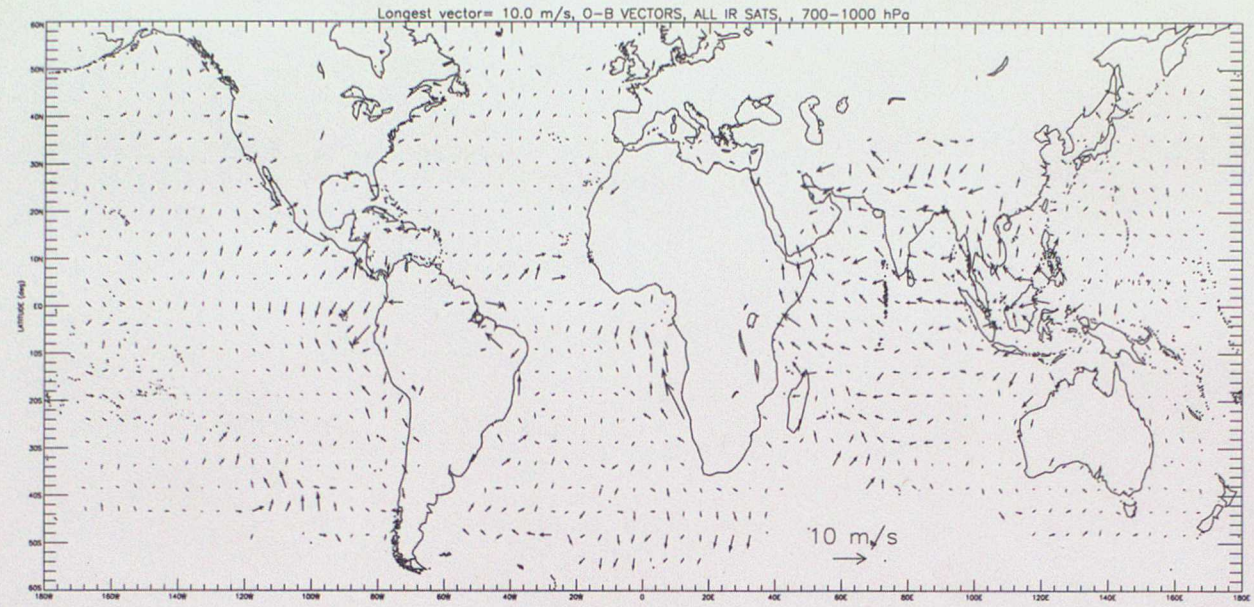
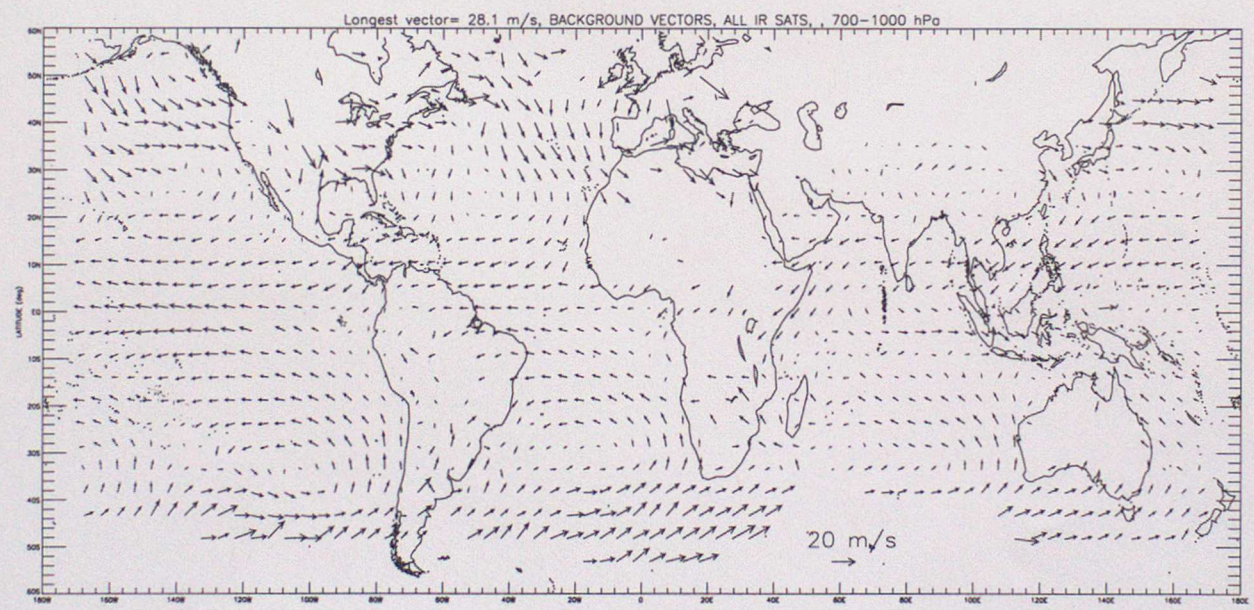


Fig. 4(c). Plots of O–B vector differences, observation and background vectors for IR satellite winds, December 1996: 701–1000 hPa.





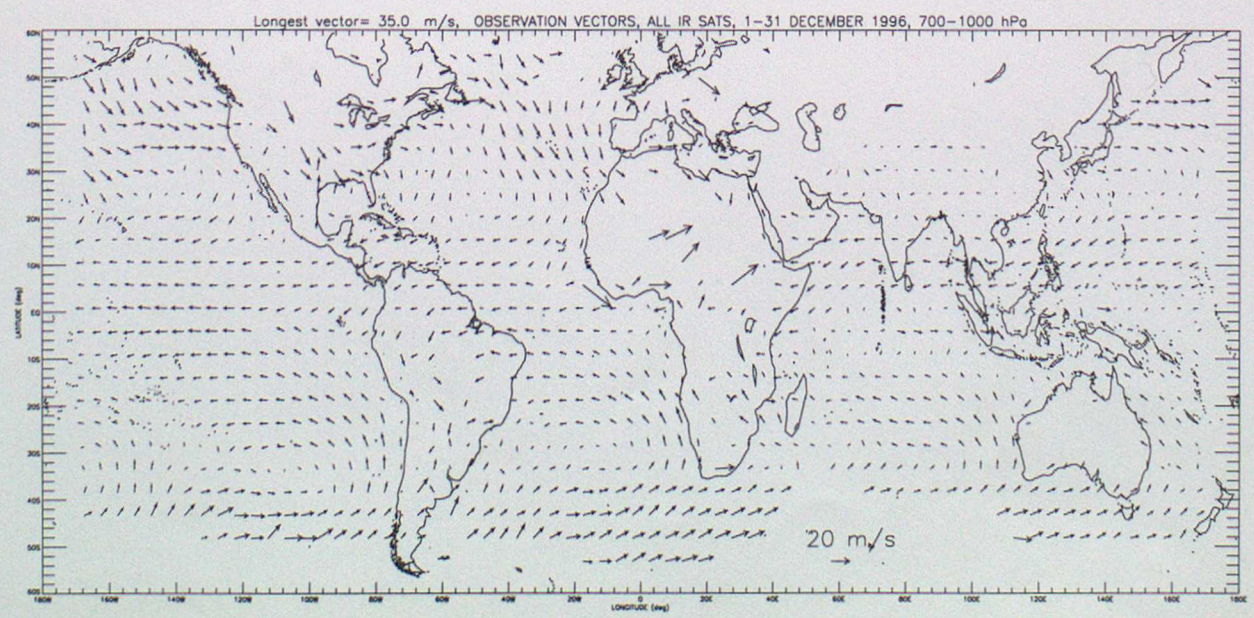
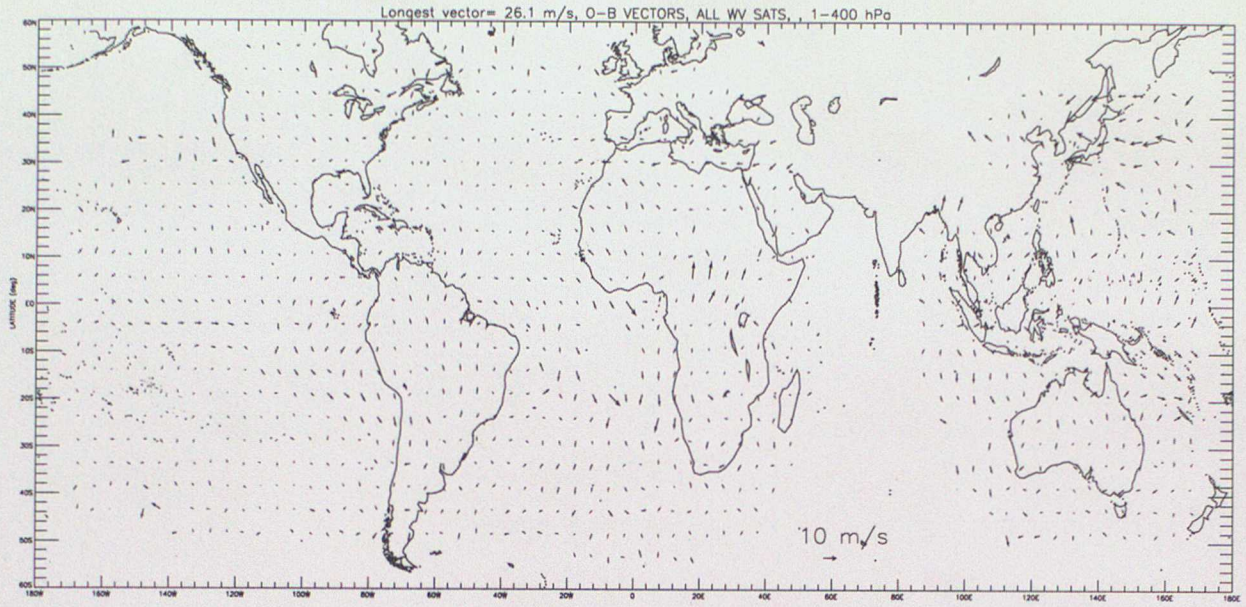
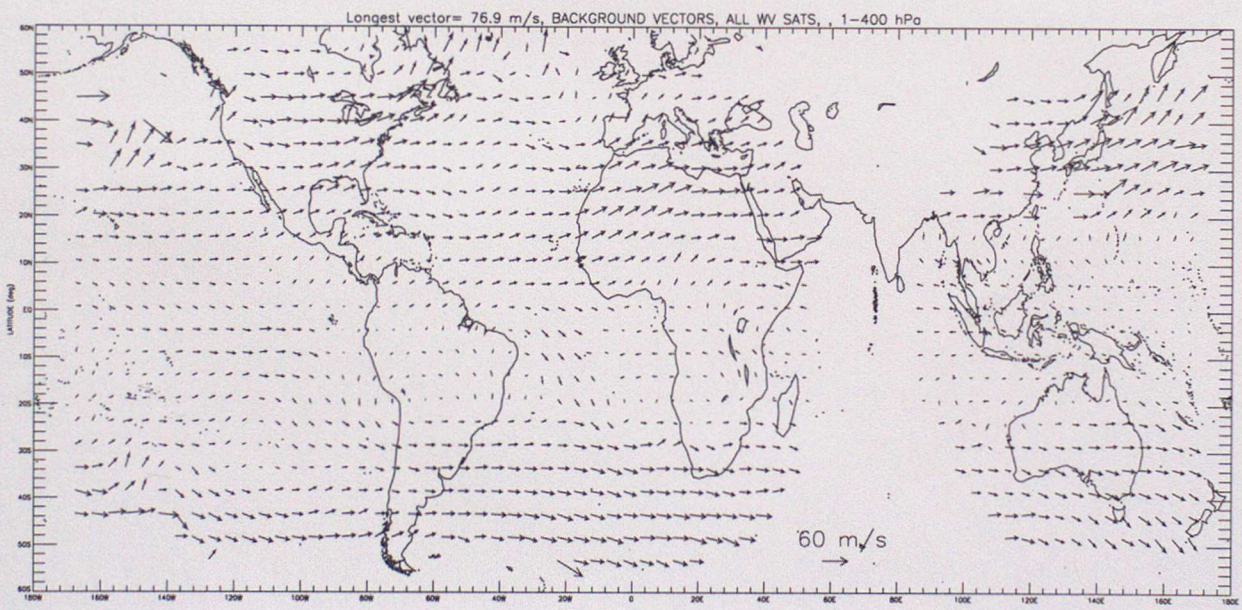


Fig. 5(a). Plots of O–B vector differences, observation and background vectors for WV satellite winds, December 1996: 1–400 hPa.





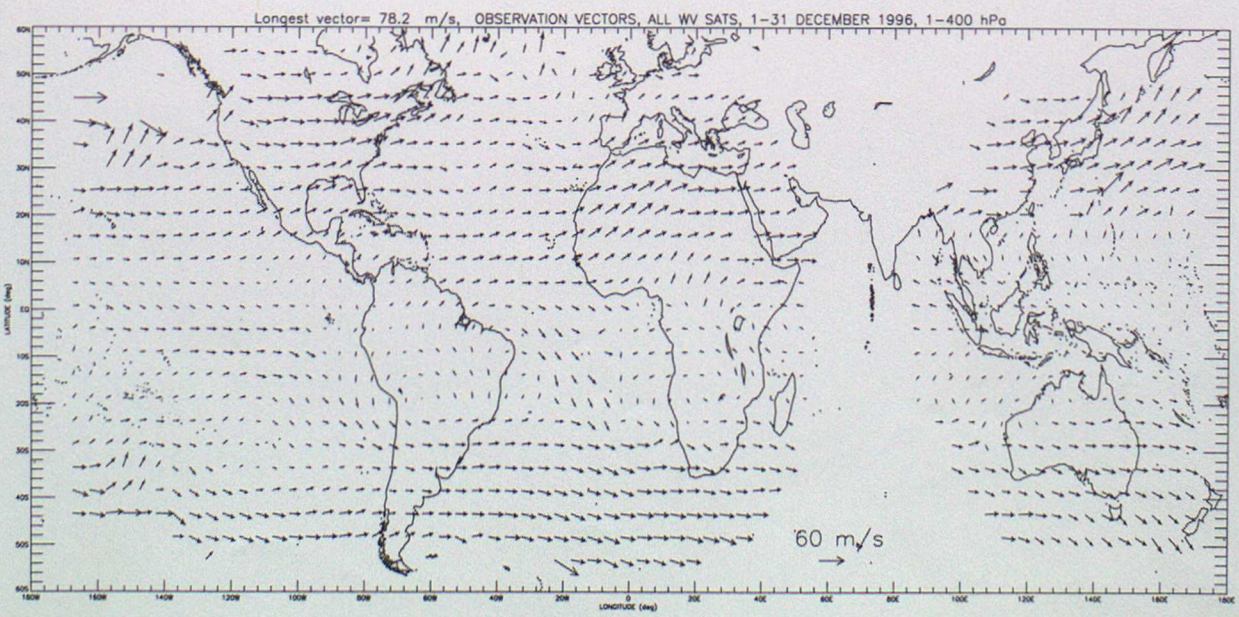
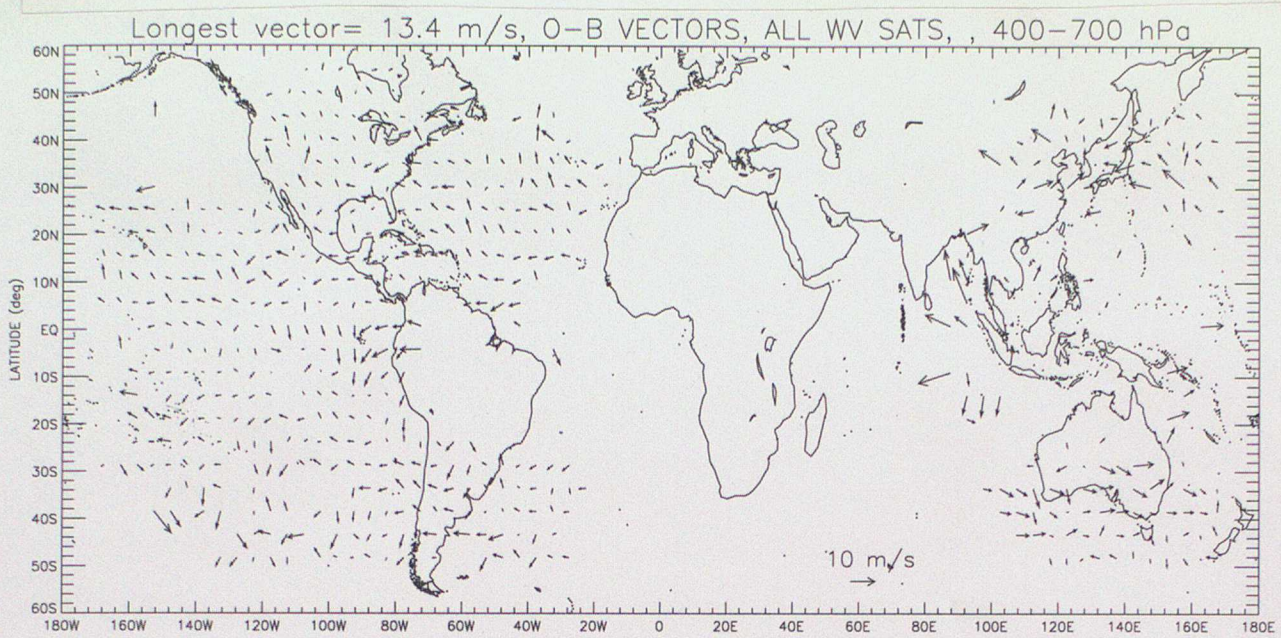
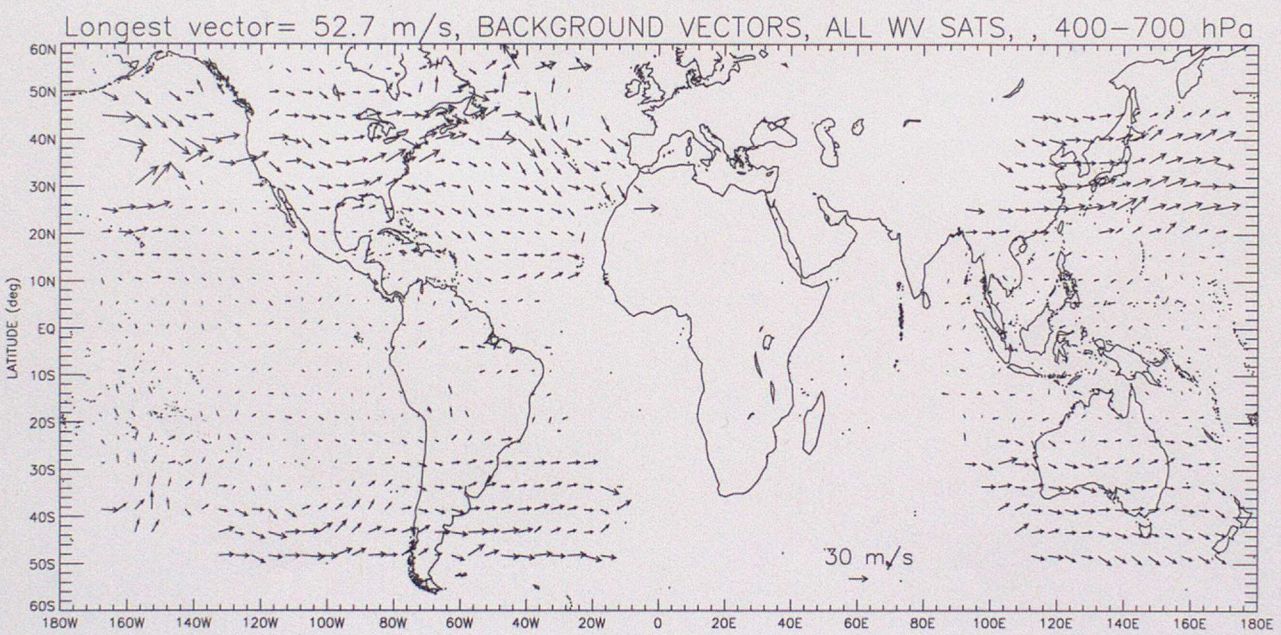


Fig. 5(b). Plots of O–B vector differences, observation and background vectors for WV satellite winds, December 1996: 401–700 hPa.





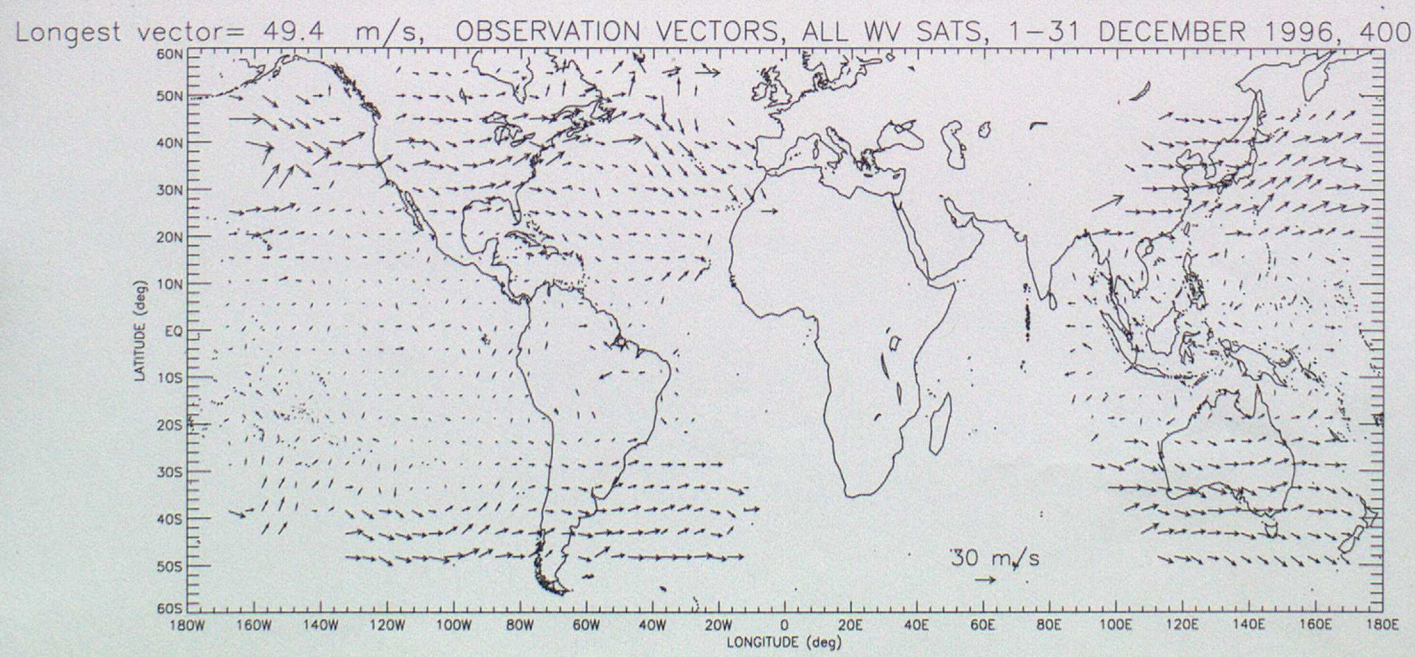
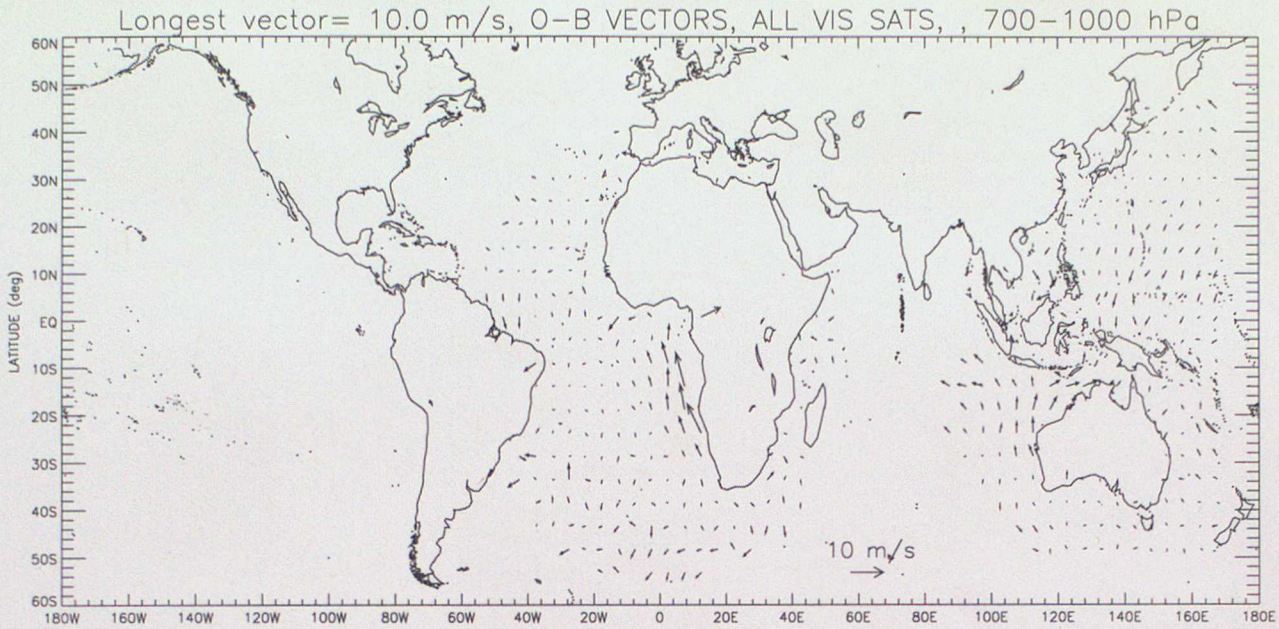
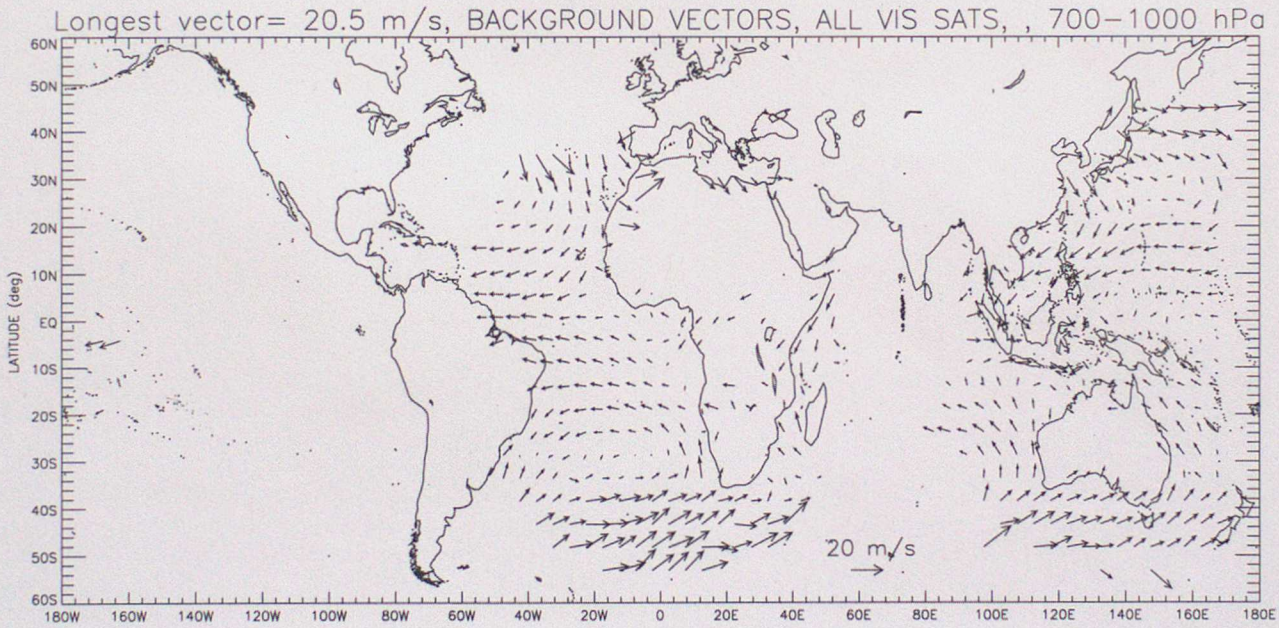


Fig. 6. Plots of O–B vector differences, observation and background vectors for VIS satellite winds, December 1996, 701–1000 hPa.





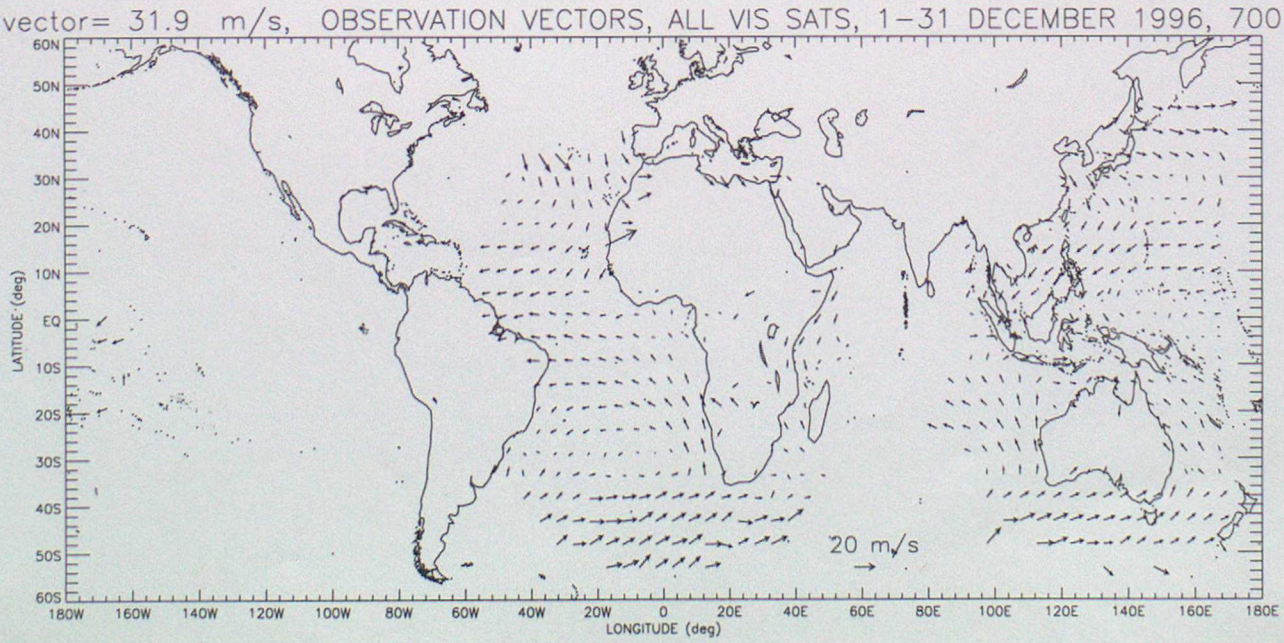
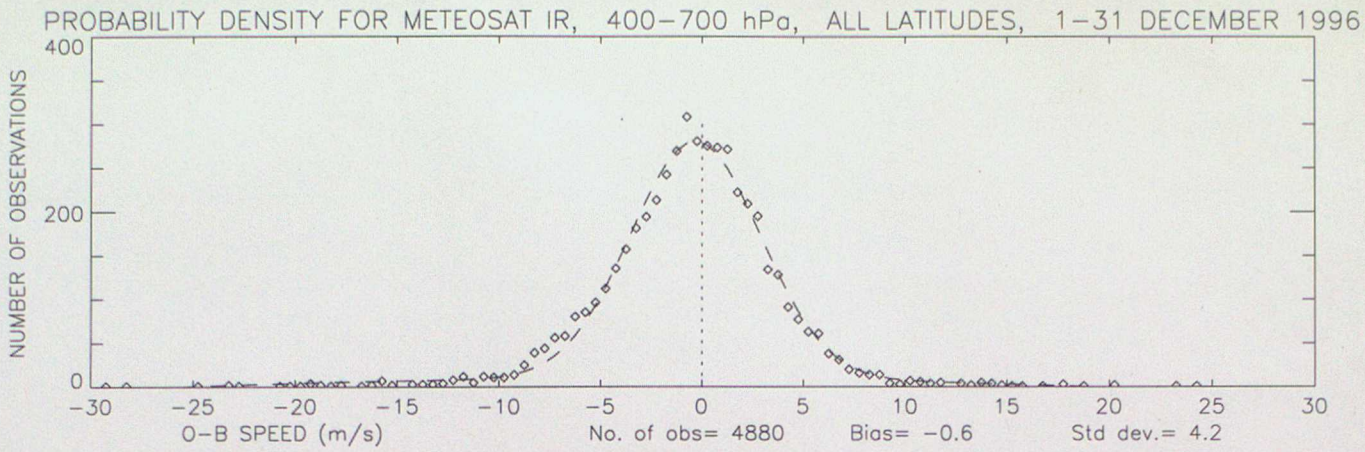
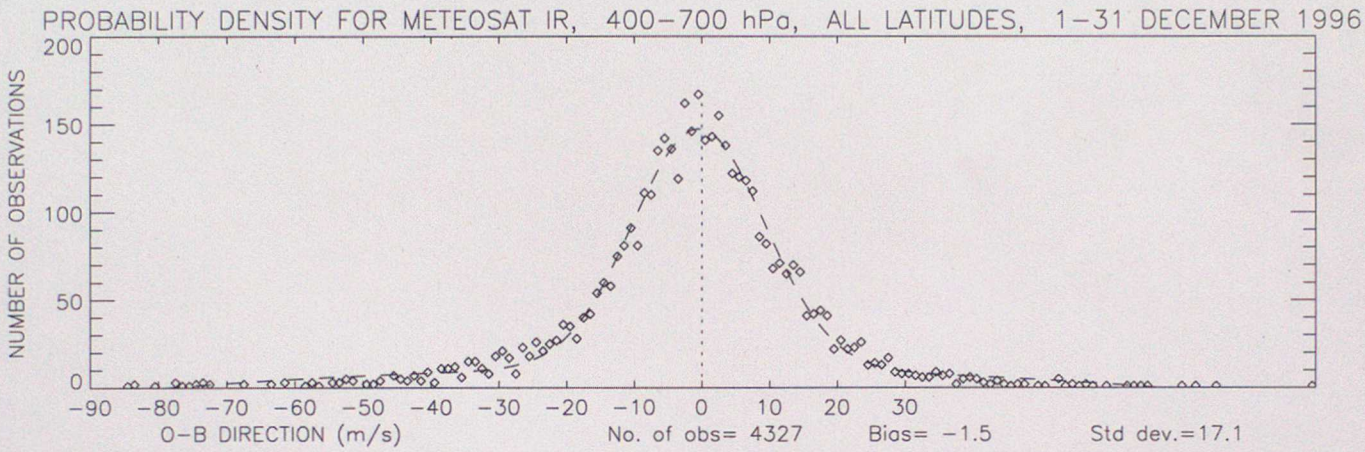
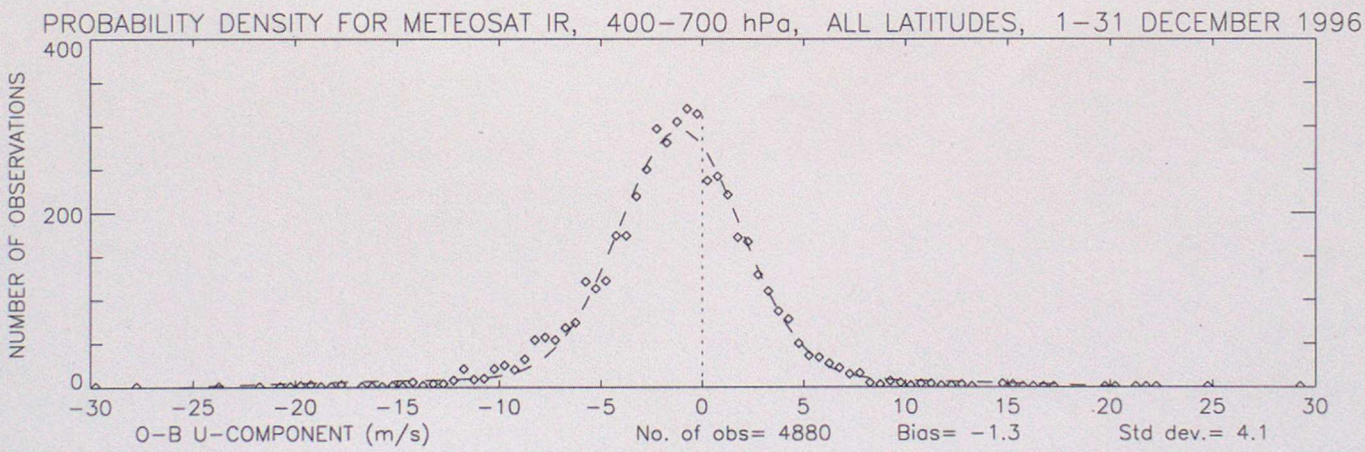


Fig. 7. Probability density plots of O–B differences in speed, direction, u- and v-components, December 1996: Meteosat IR, 401–700 hPa.







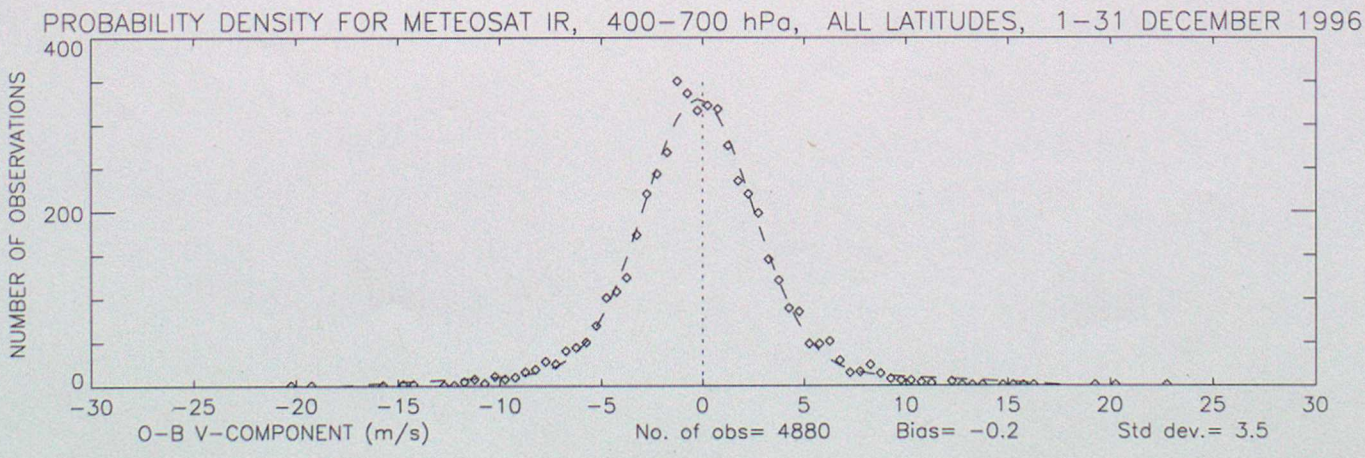
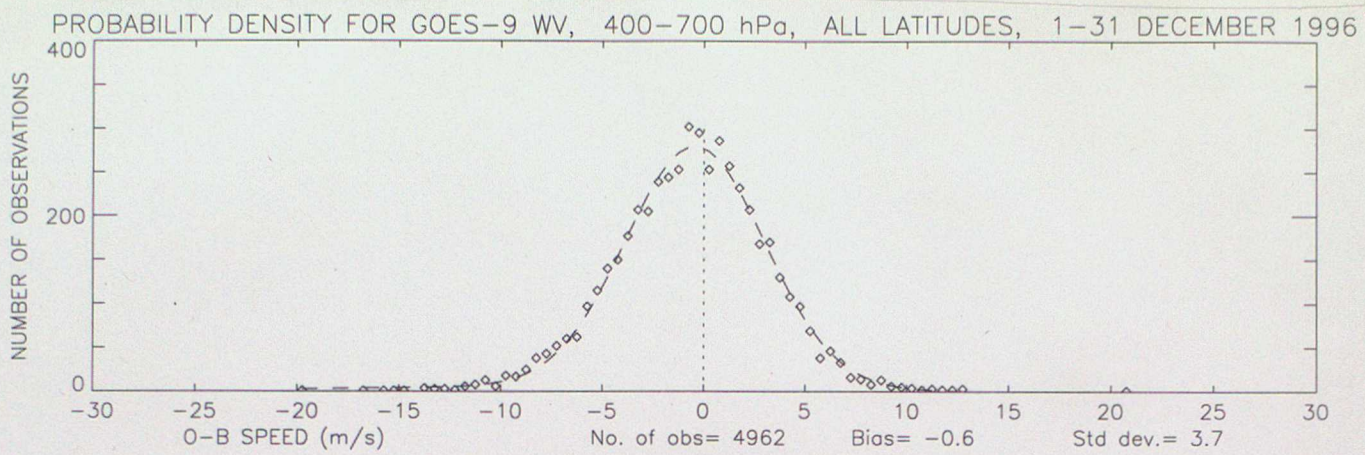
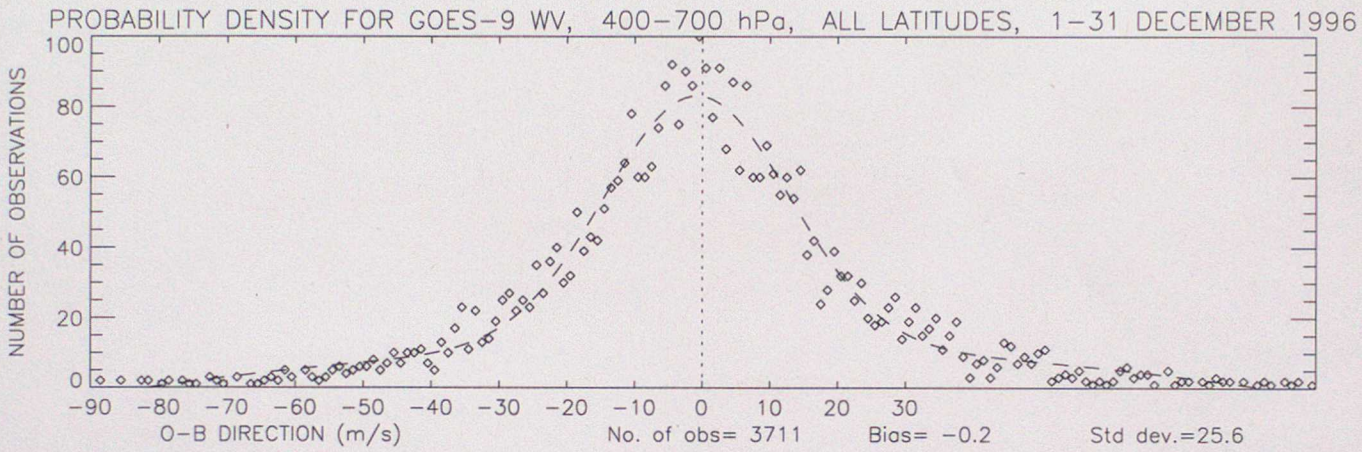
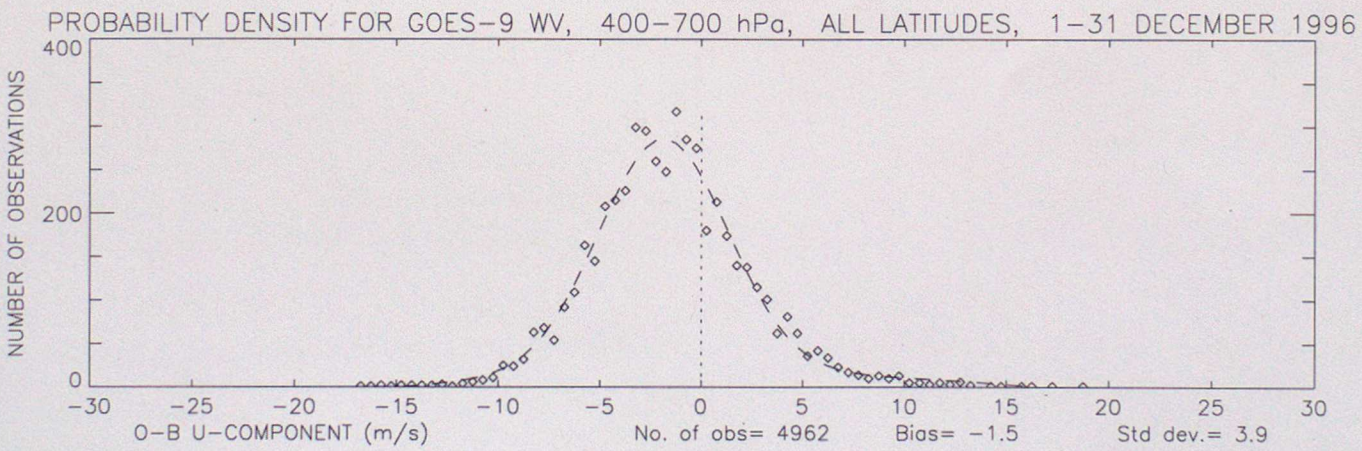


Fig. 8. Probability density plots of O–B differences in speed, direction, u- and v-components, December 1996: GOES-9 WV, 401–700 hPa.







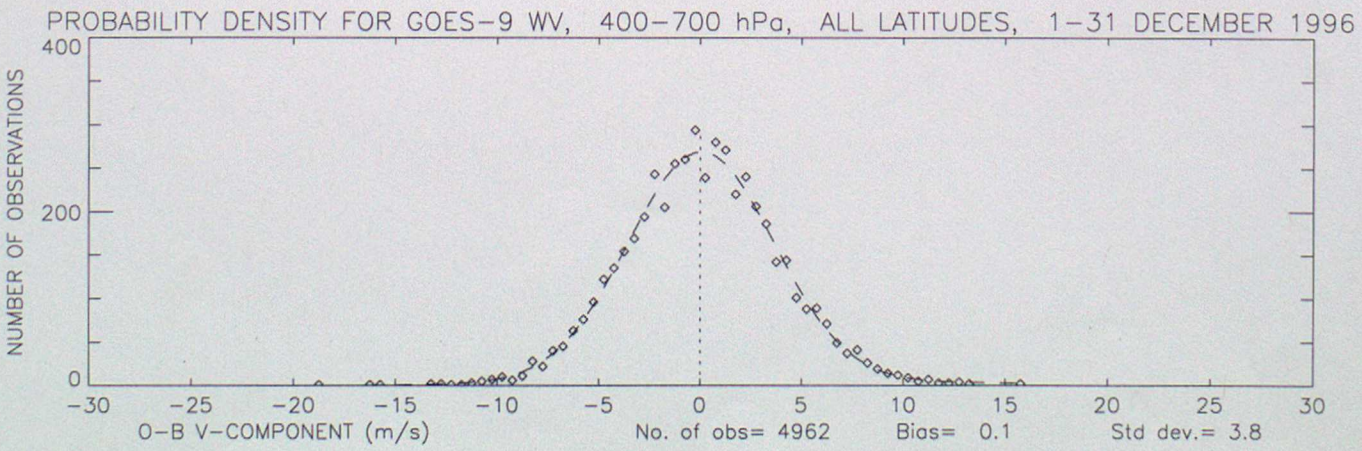
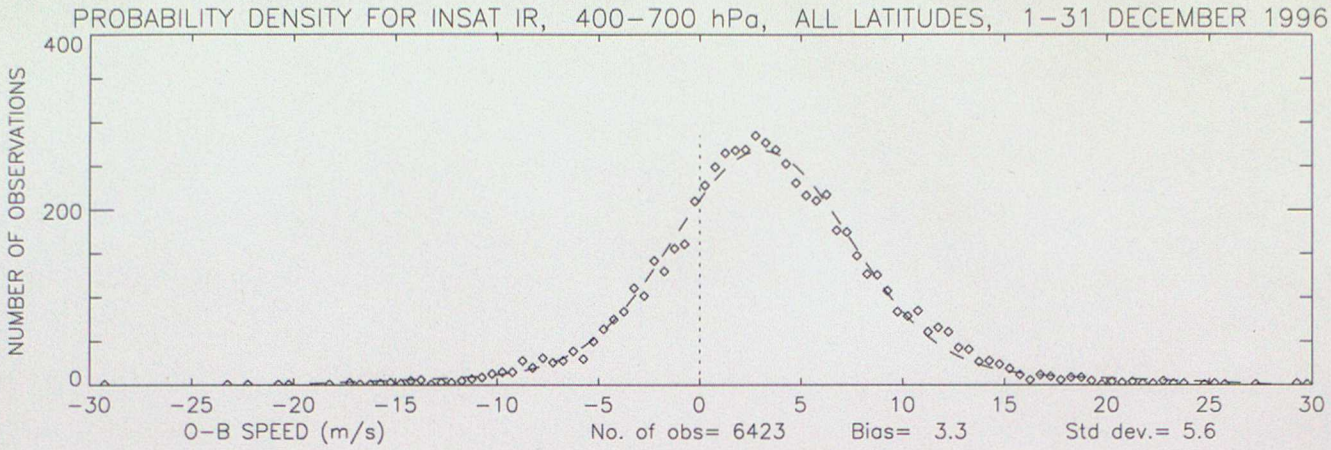
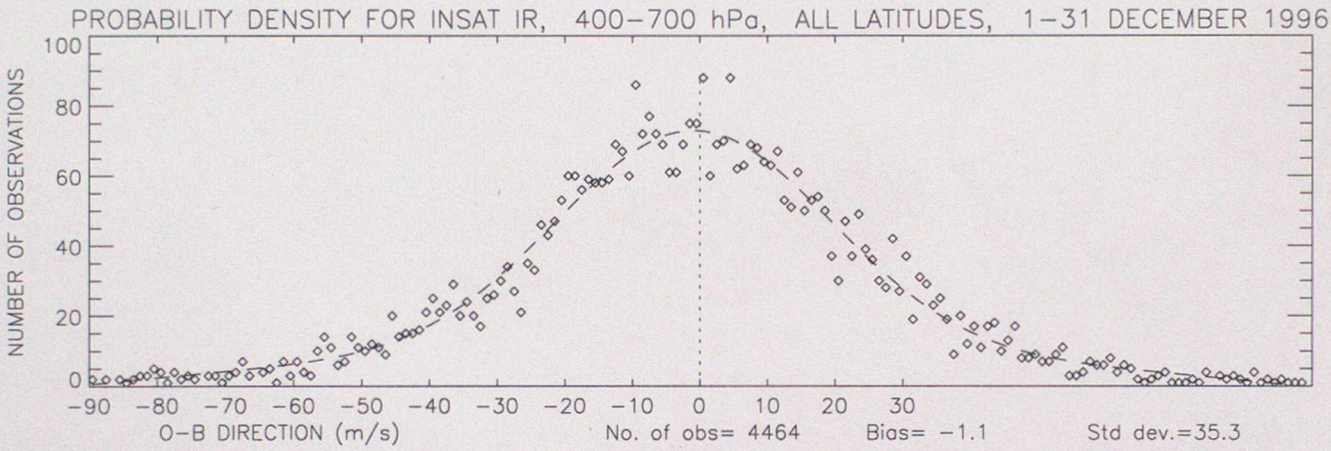
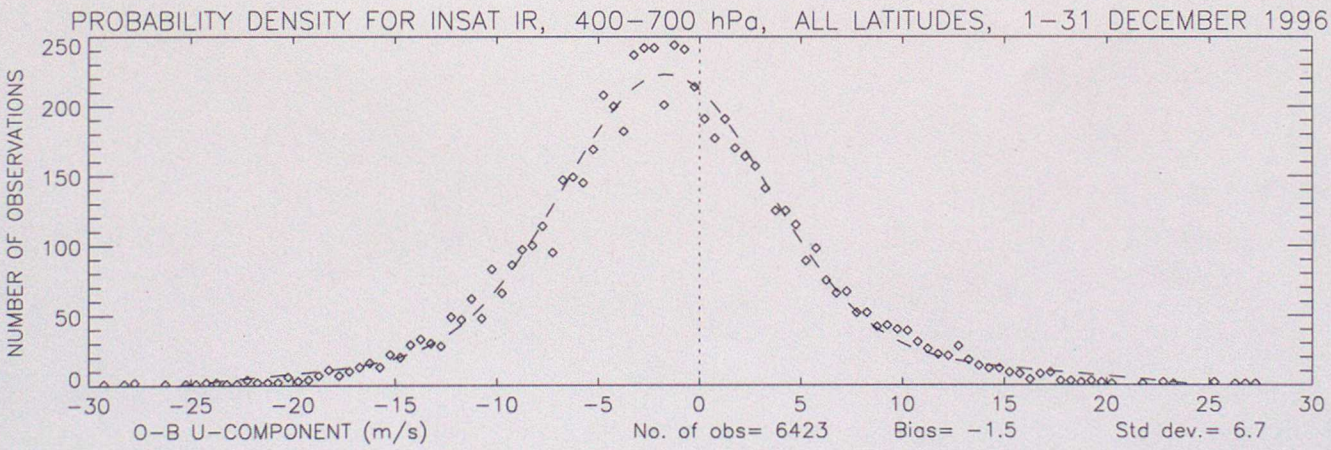


Fig. 9. Probability density plots of O–B differences in speed, direction, u- and v-components, December 1996: INSAT IR, 401–700 hPa.







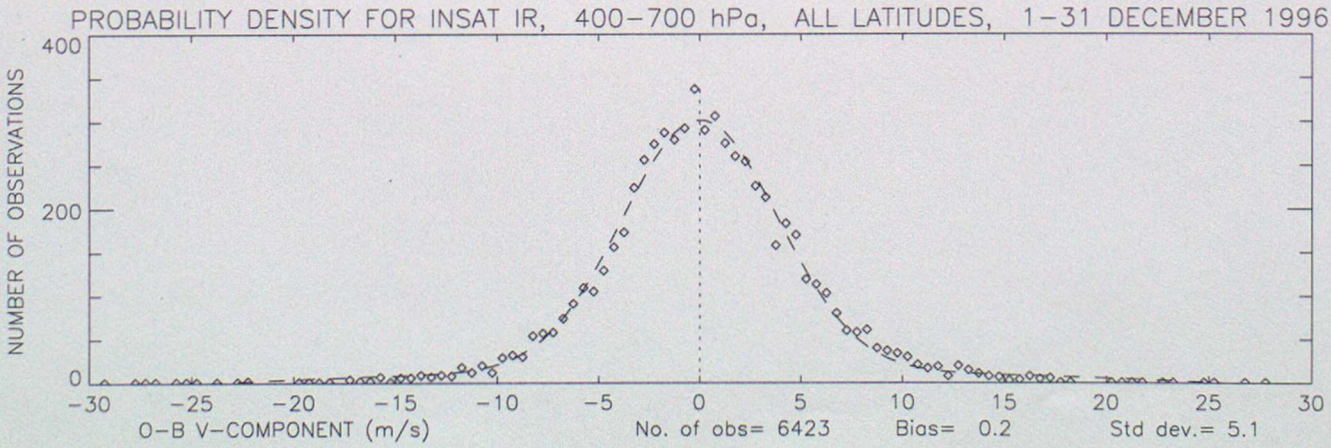
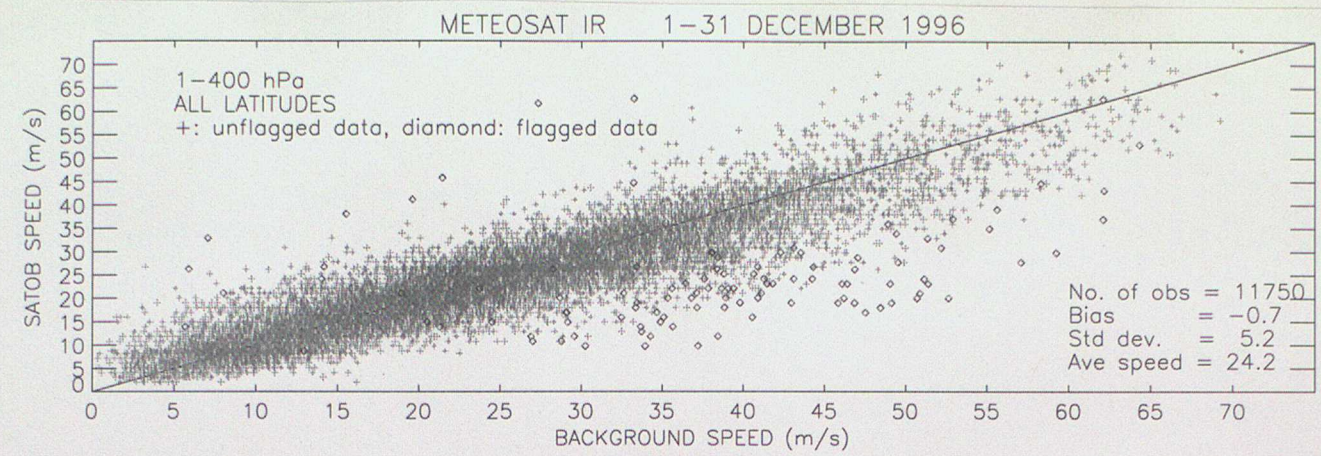
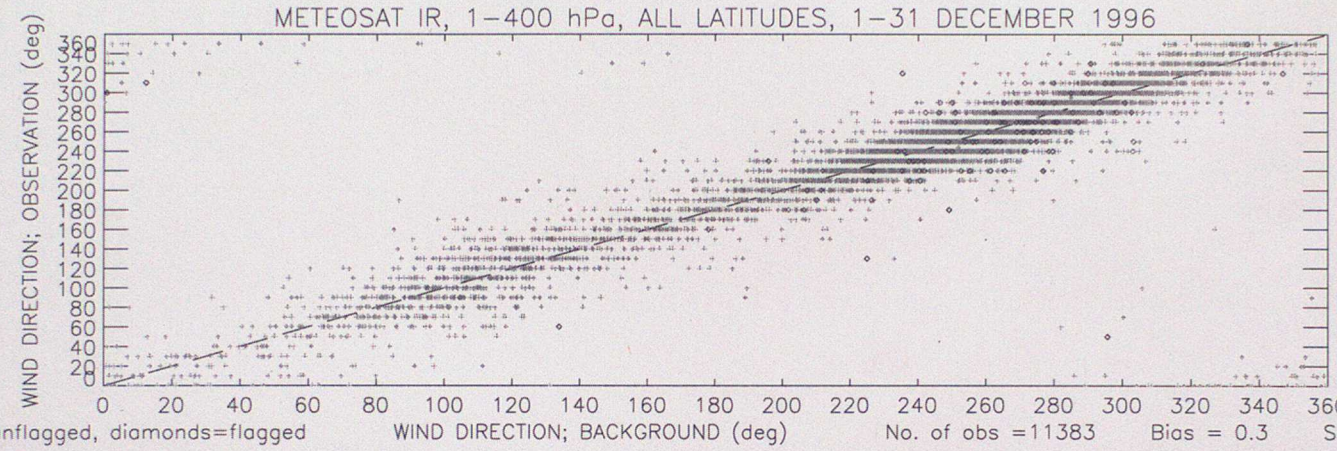
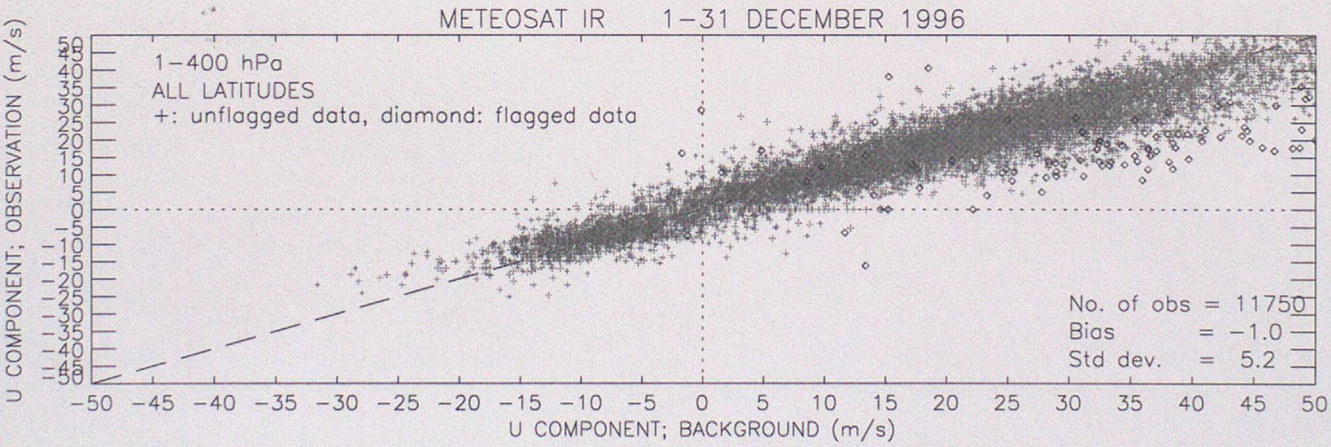


Fig. 10(a). Scatter plots of O vs B speed, direction, u- and v-components, December 1996: Meteosat IR, 1–400 hPa.







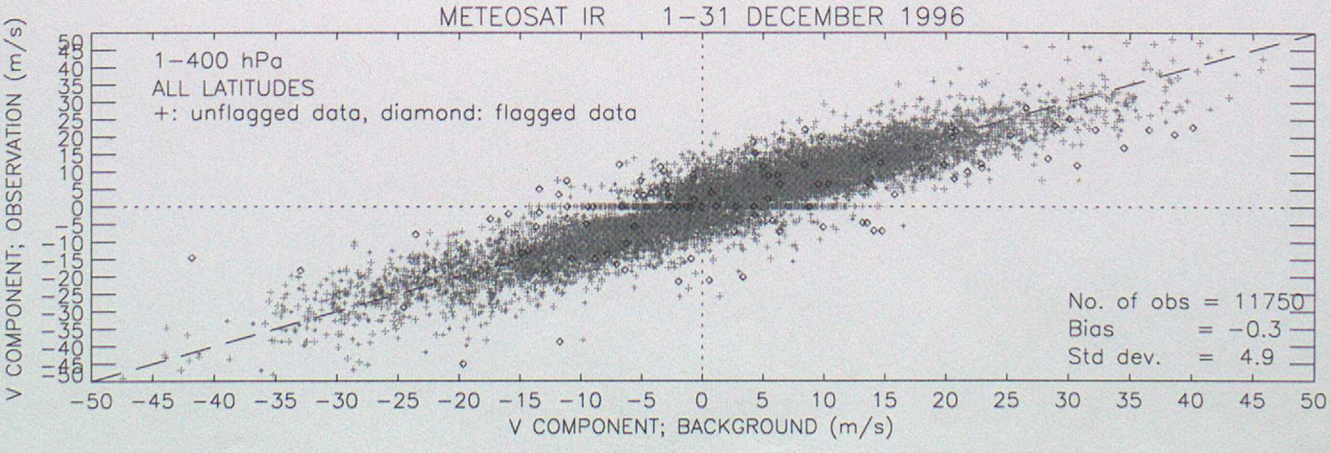
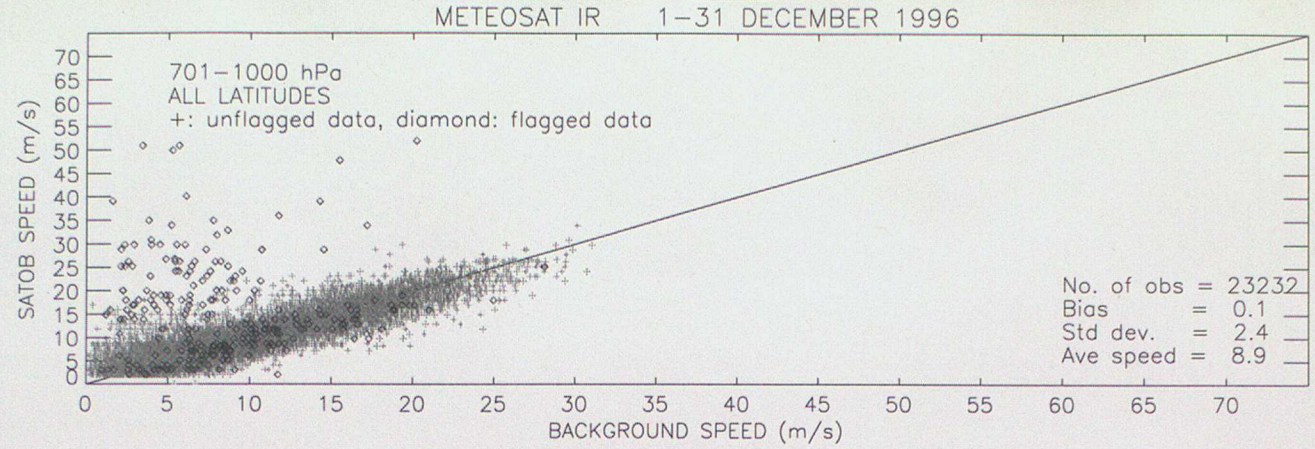
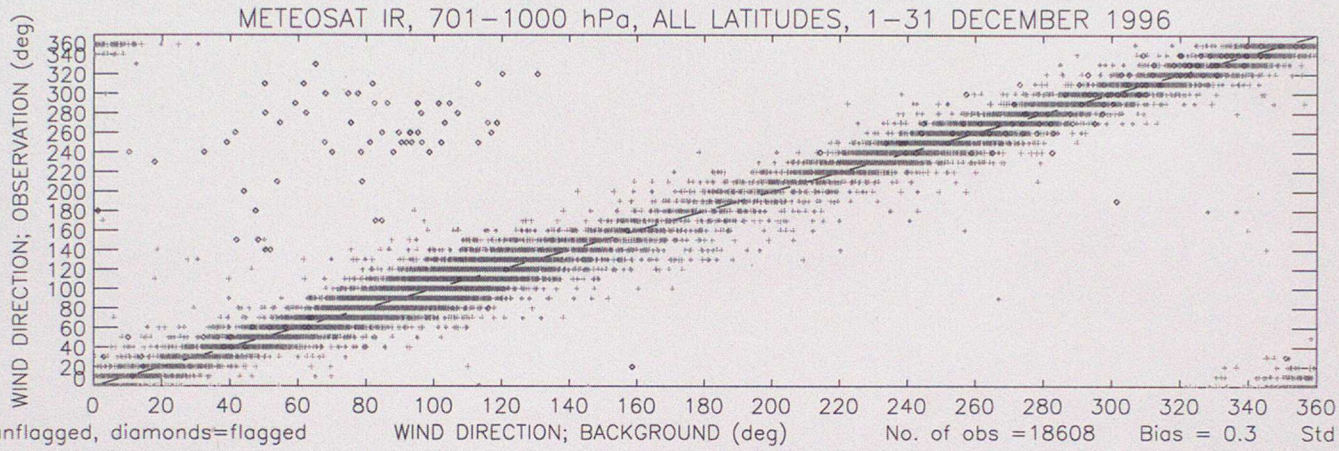
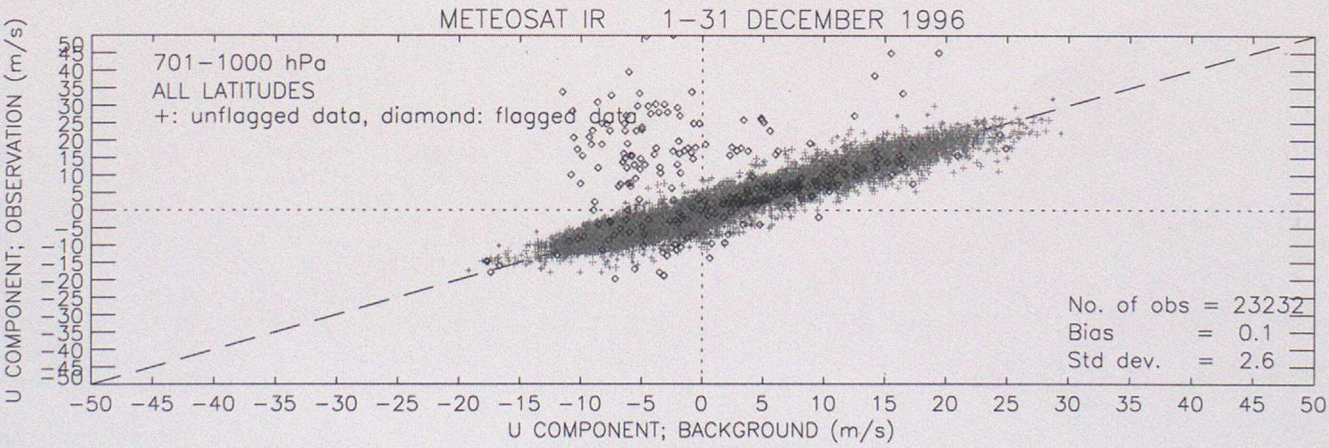


Fig. 10(b). Scatter plots of O vs B speed, direction, u- and v-components, December 1996: Meteosat IR, 701–1000 hPa.







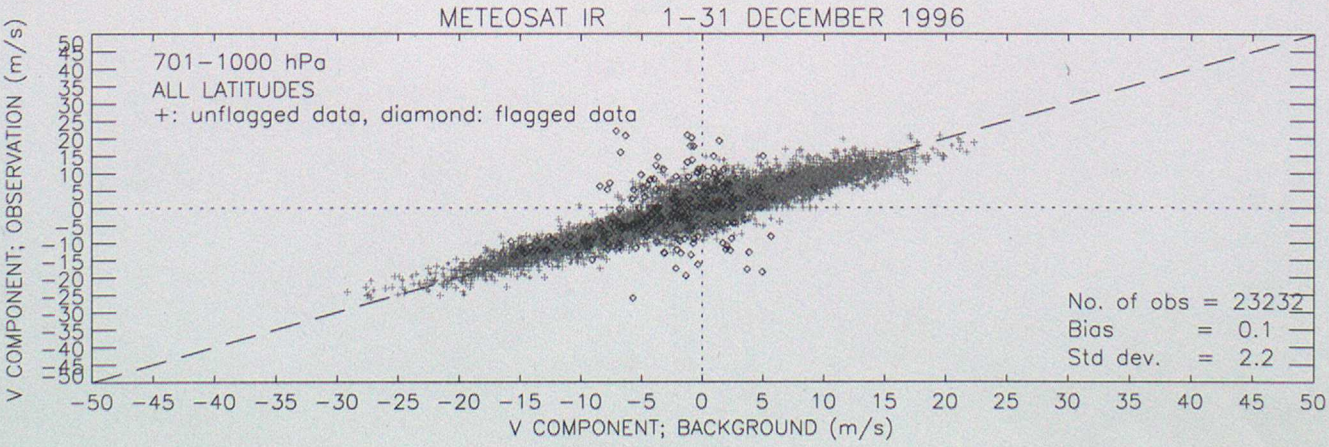


Fig. 11. Scatter plots of O vs B speed, direction, u- and v-components, December 1996: GOES-9 IR, 1–400 hPa.

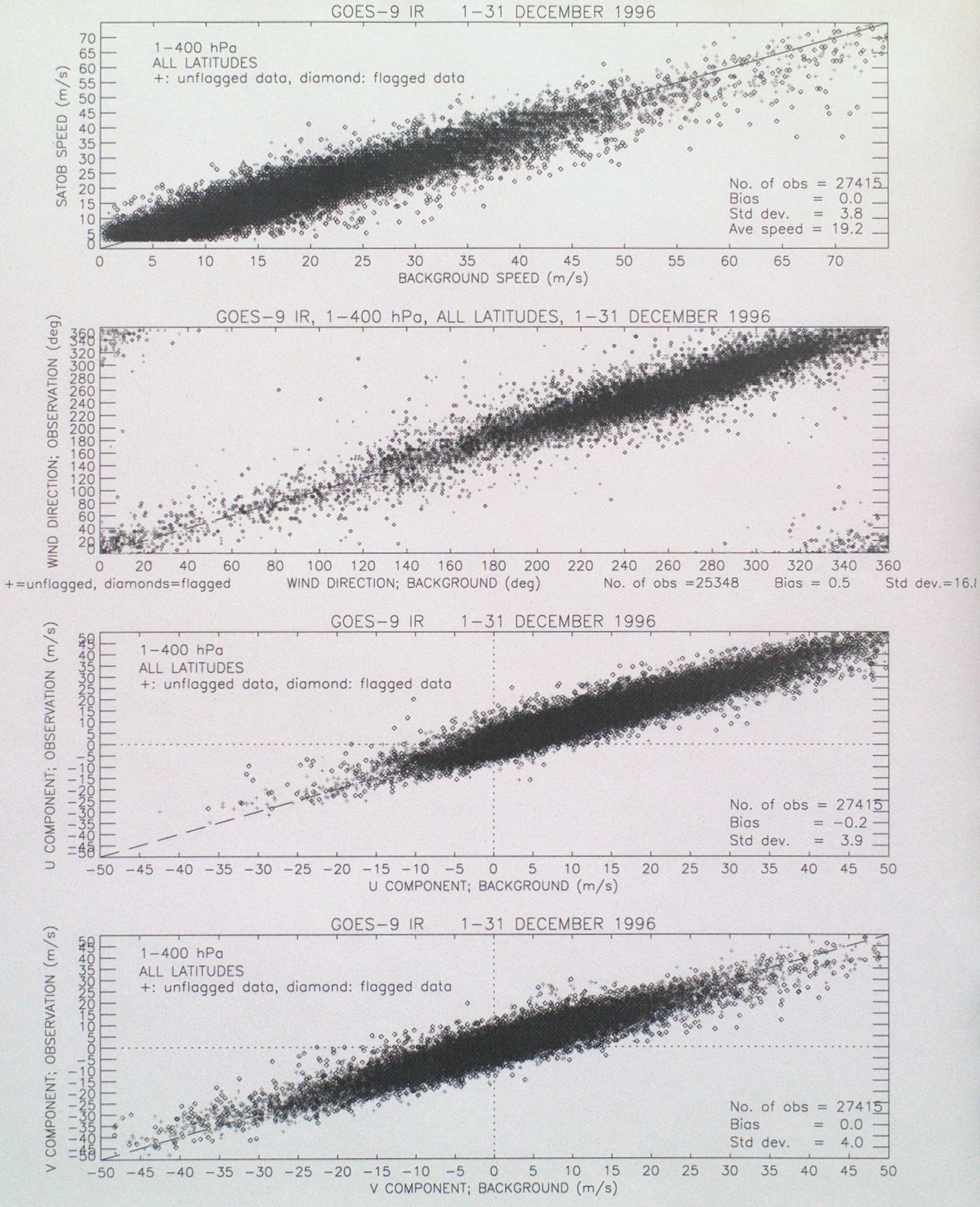
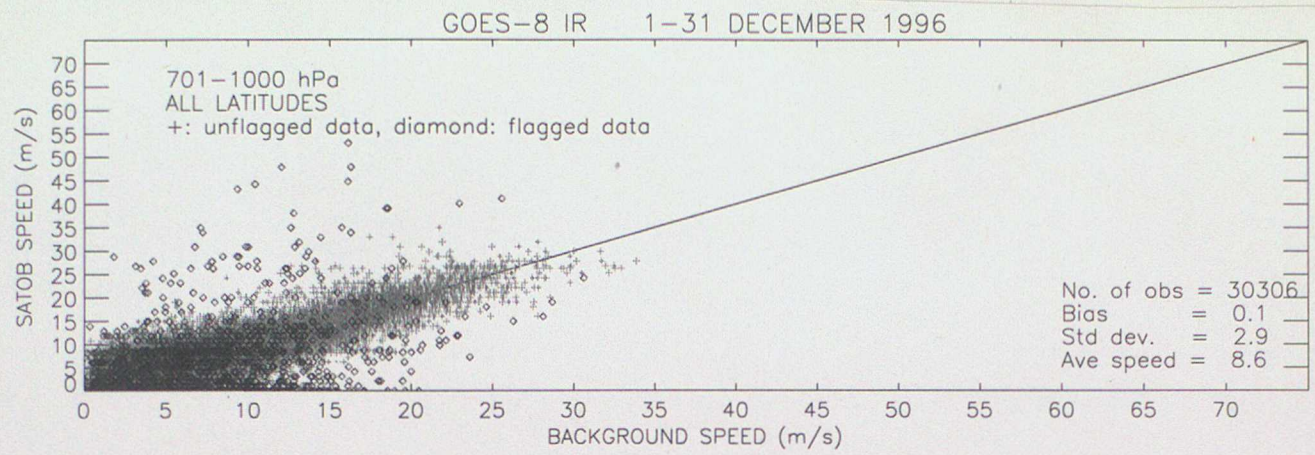
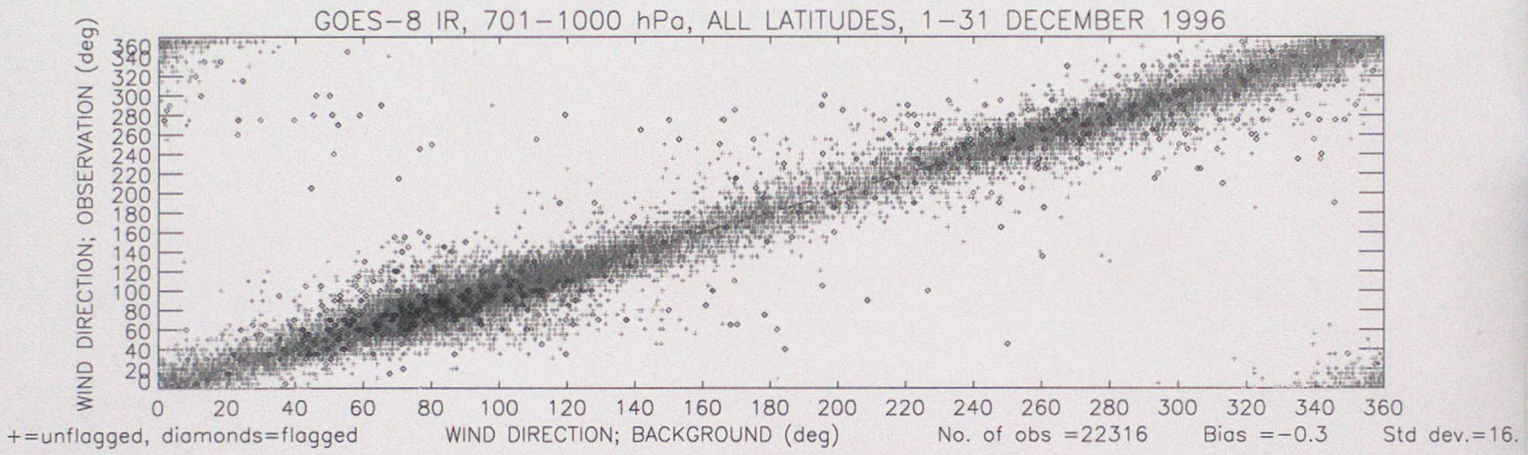
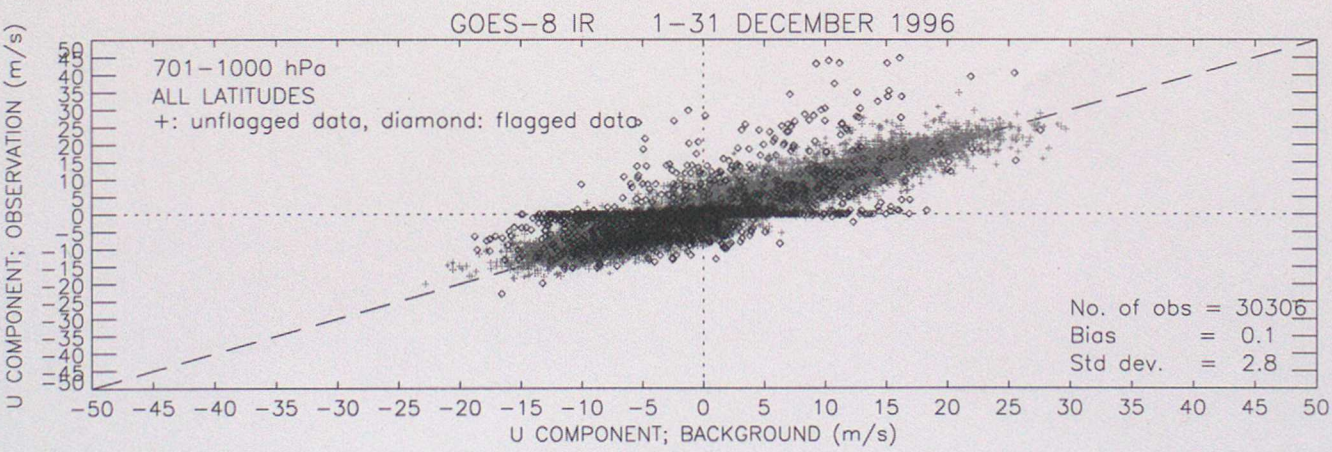


Fig. 12. Scatter plots of O vs B speed, direction, u- and v-components, December 1996: GOES-8 IR, 701-1000 hPa.







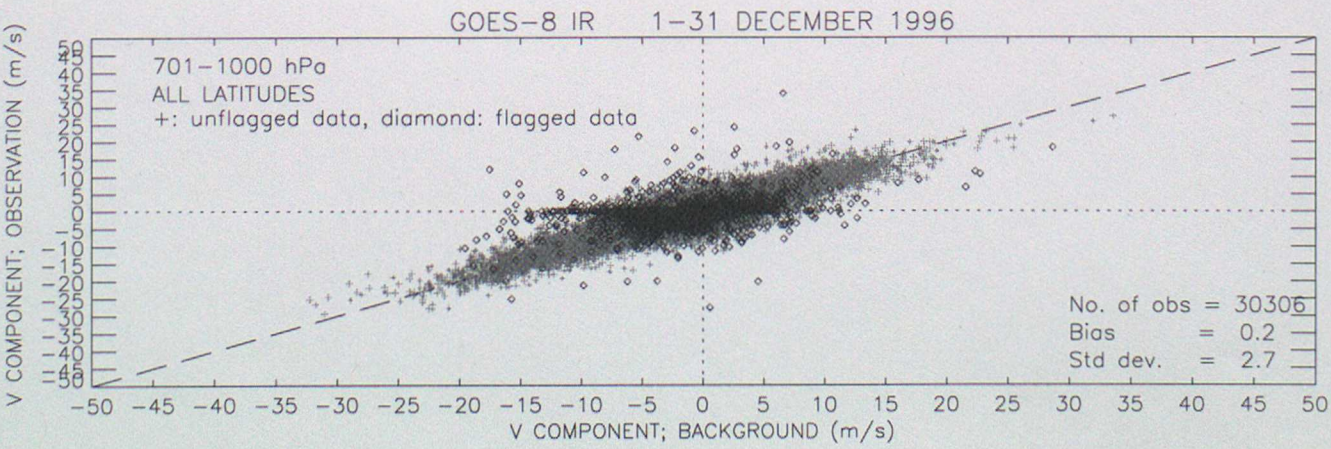


Fig. 13. Example contour plots of O vs B speed, December 1996: Meteosat IR, GOES-9 IR, GMS IR, Meteosat WV, 1–400 hPa, northern hemisphere.

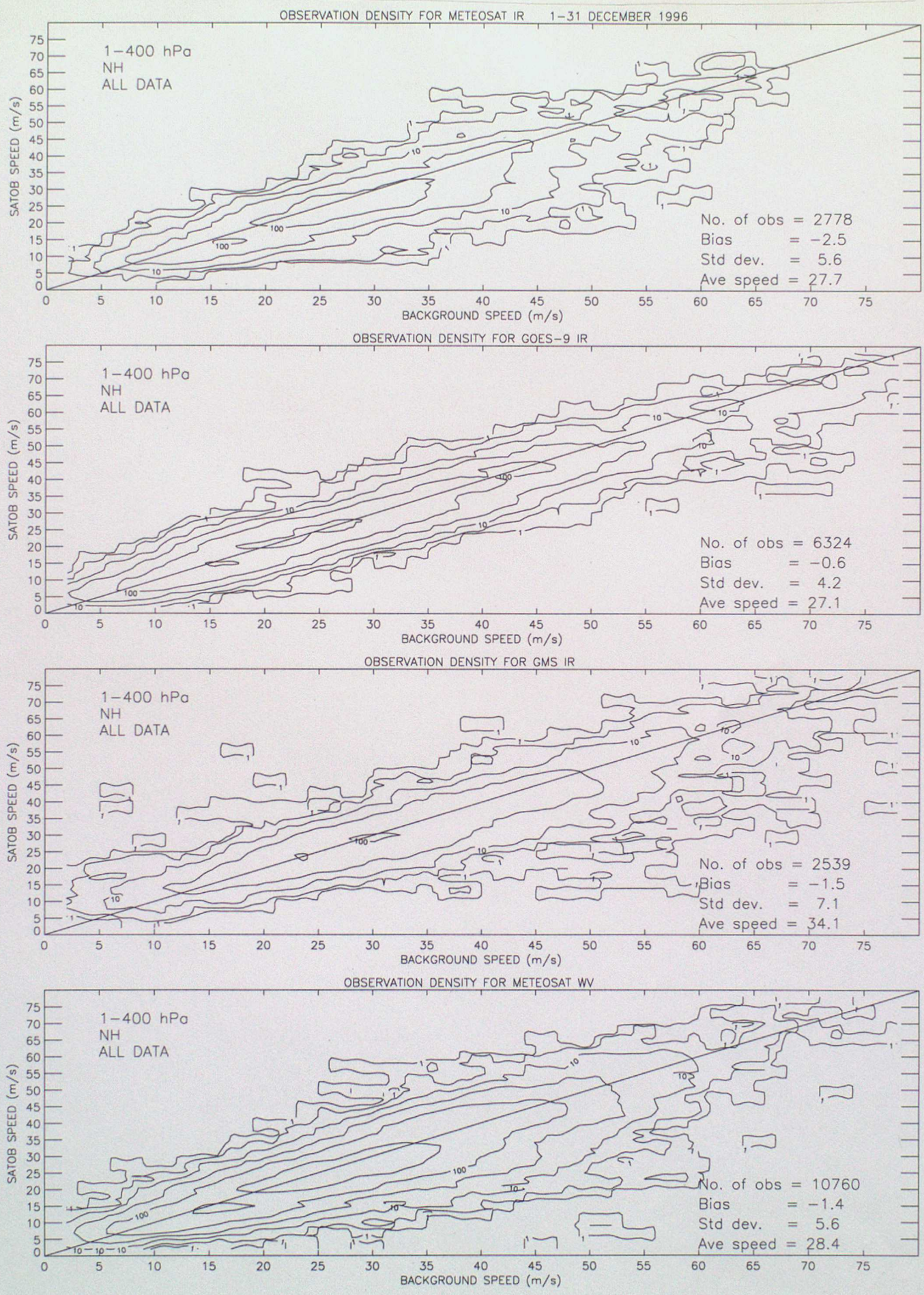
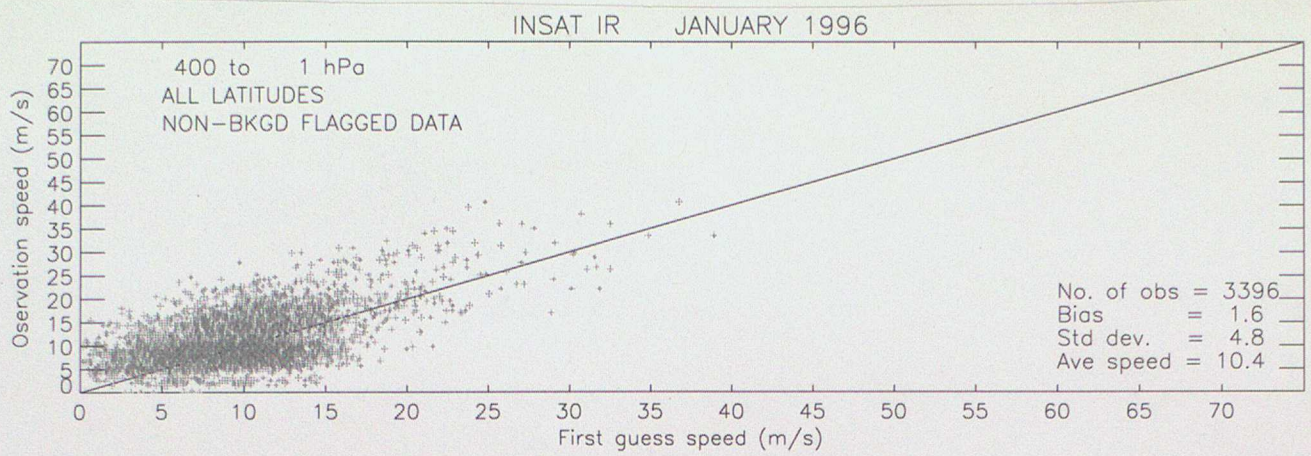
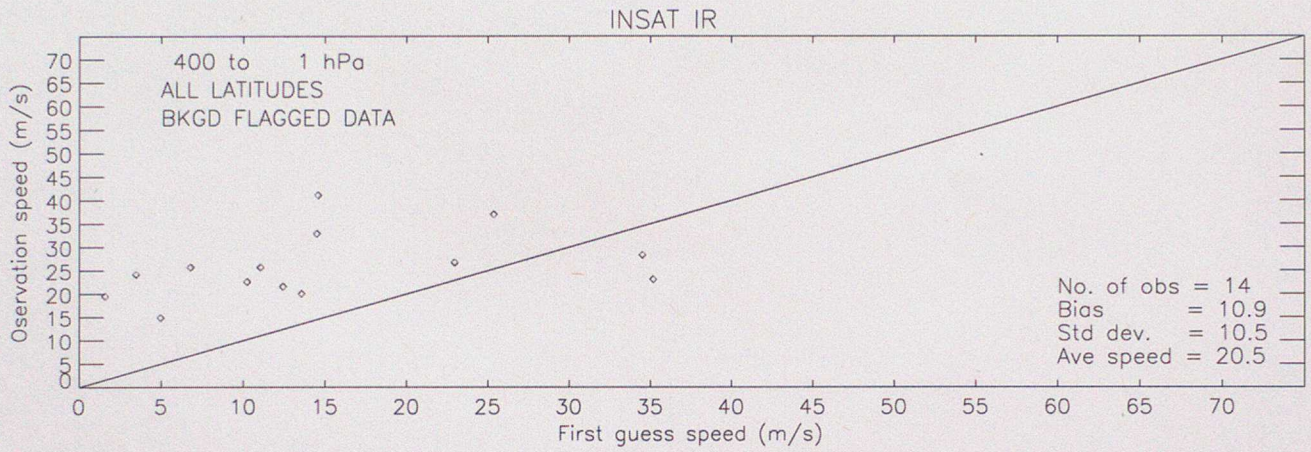
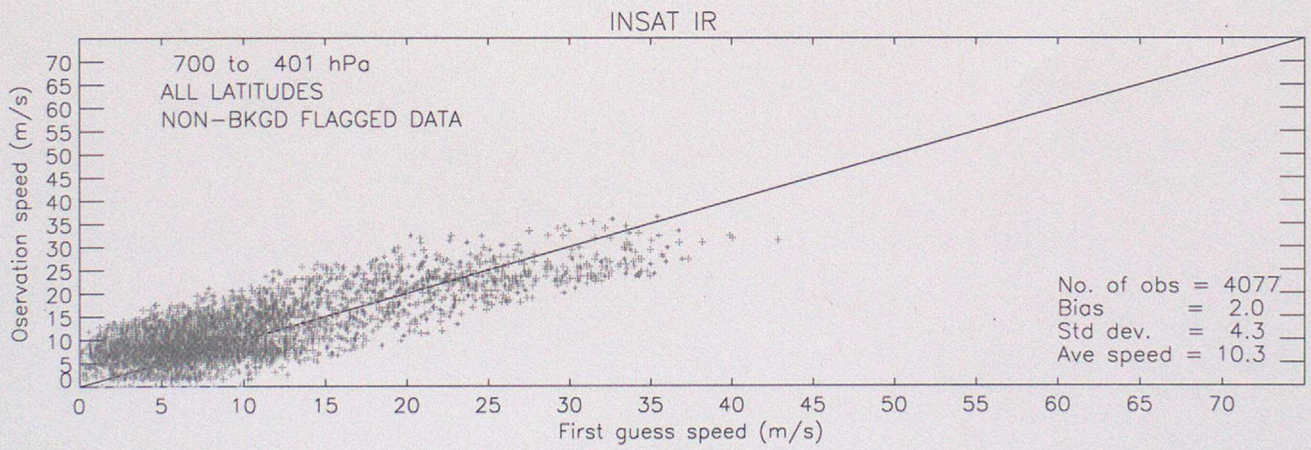


Fig. 14(a). Fully blacklisted data types; difference between non-background-flagged and background-flagged data: INSAT IR, 1–400, 401–700 hPa.







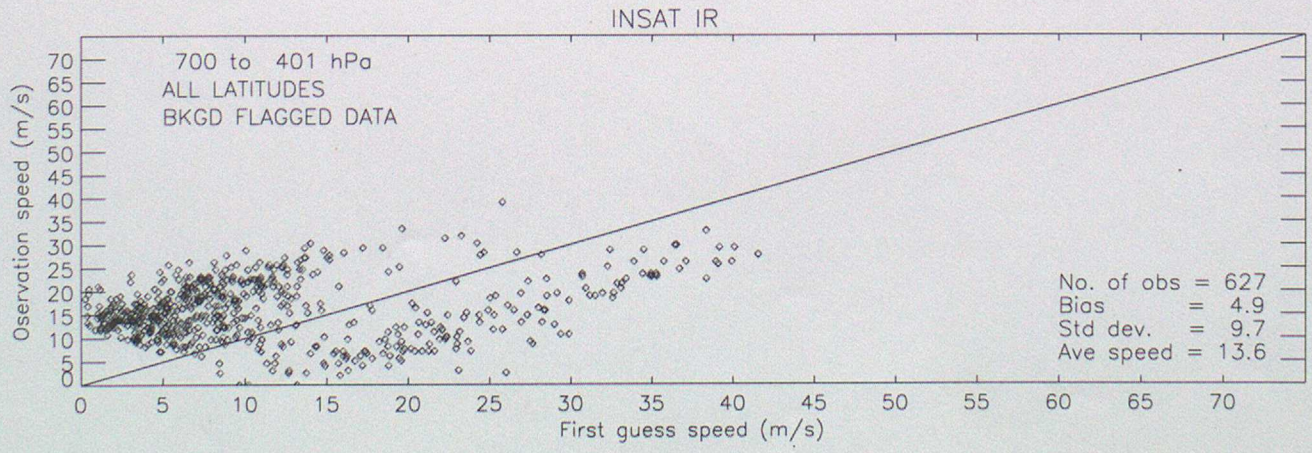
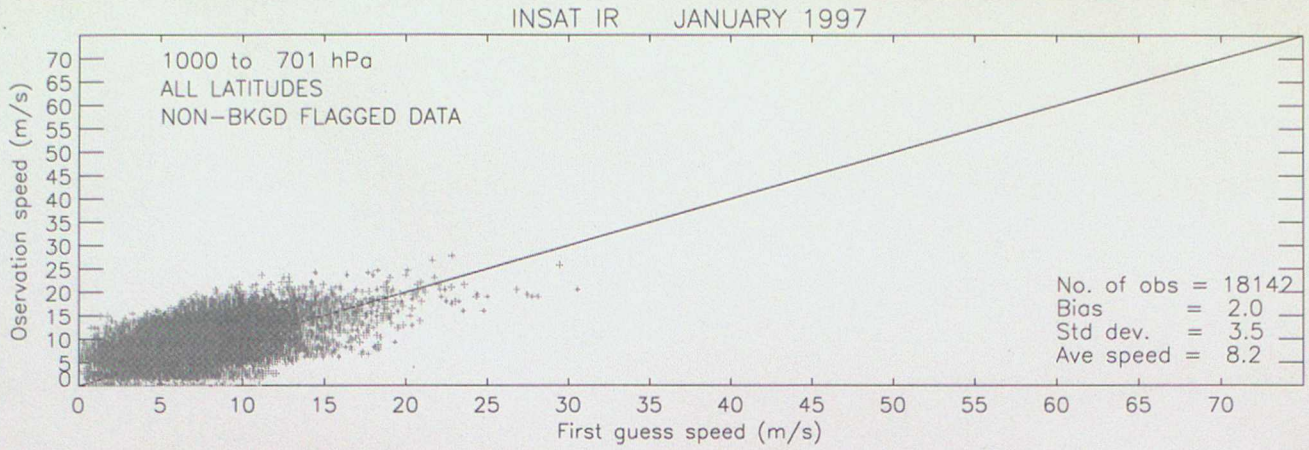
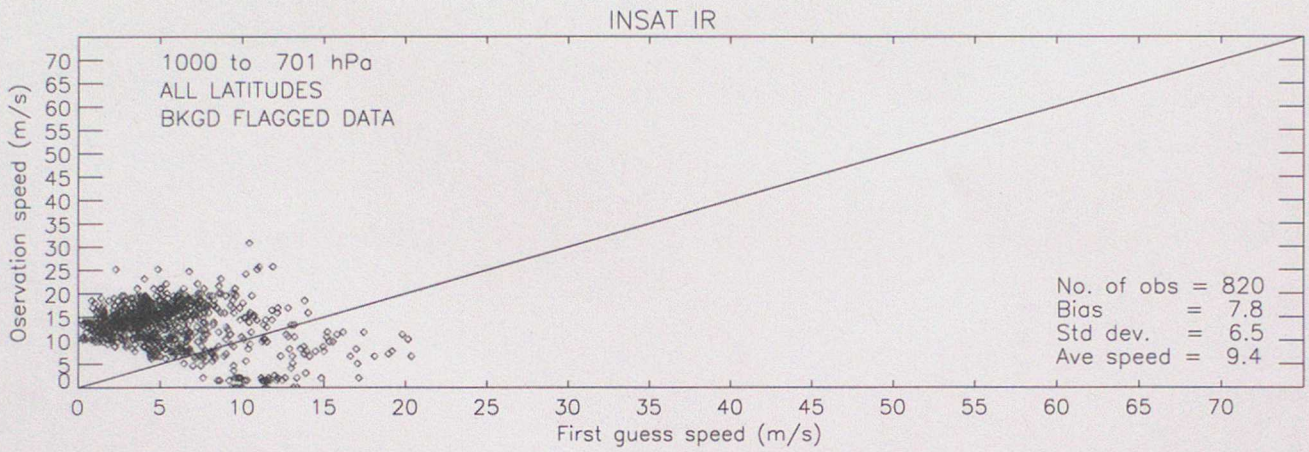
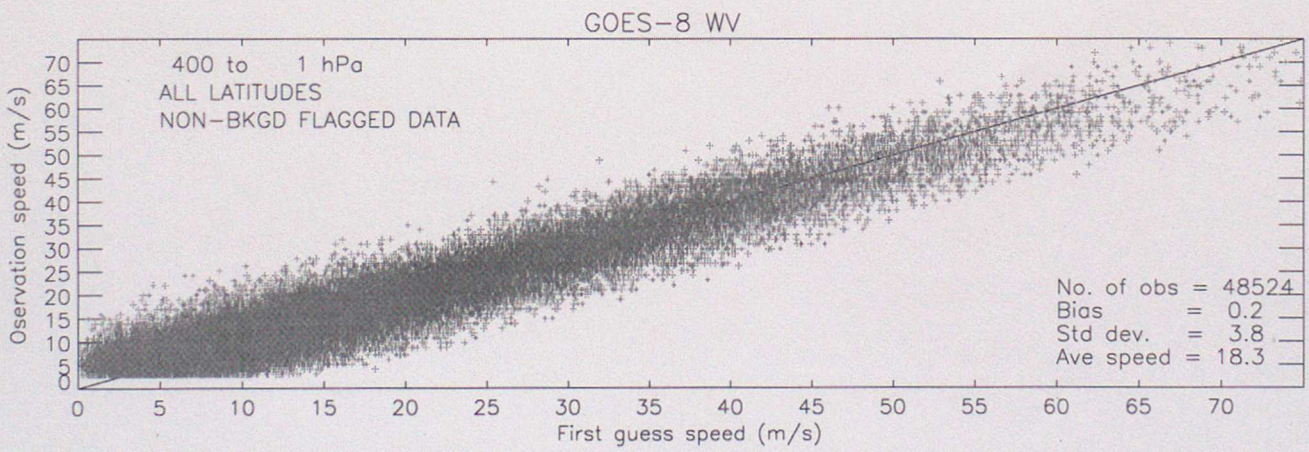


Fig. 14(b). Fully blacklisted data types; difference between non-background-flagged and background-flagged data: INSAT IR, 701–1000 hPa; GOES-8 WV, 1–400 hPa.







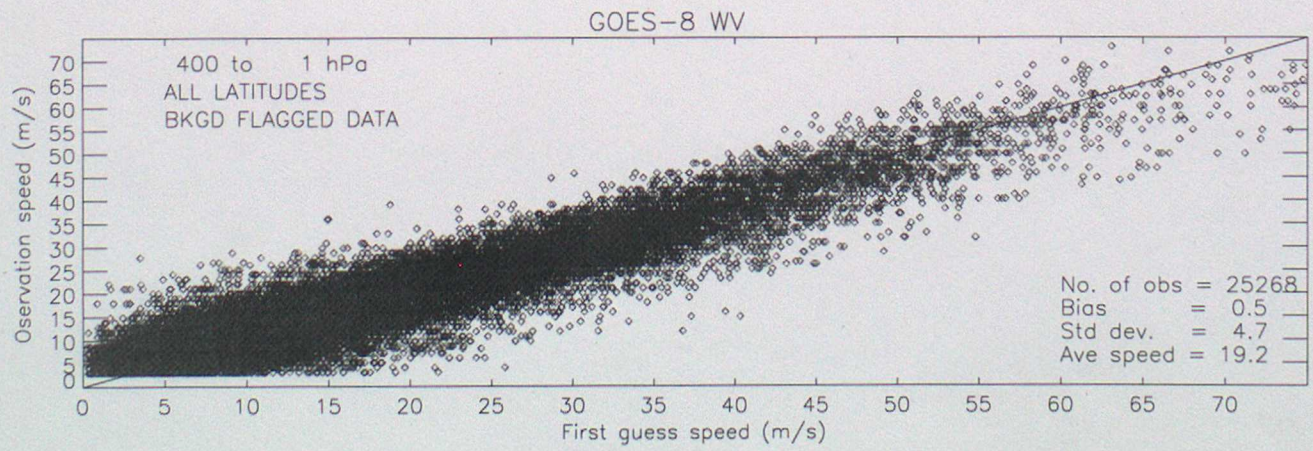


Fig. 14(c). Fully blacklisted data types; difference between non-background-flagged and background-flagged data: GOES-8 WV, 401–700 hPa; GMS WV, 1–400 hPa.

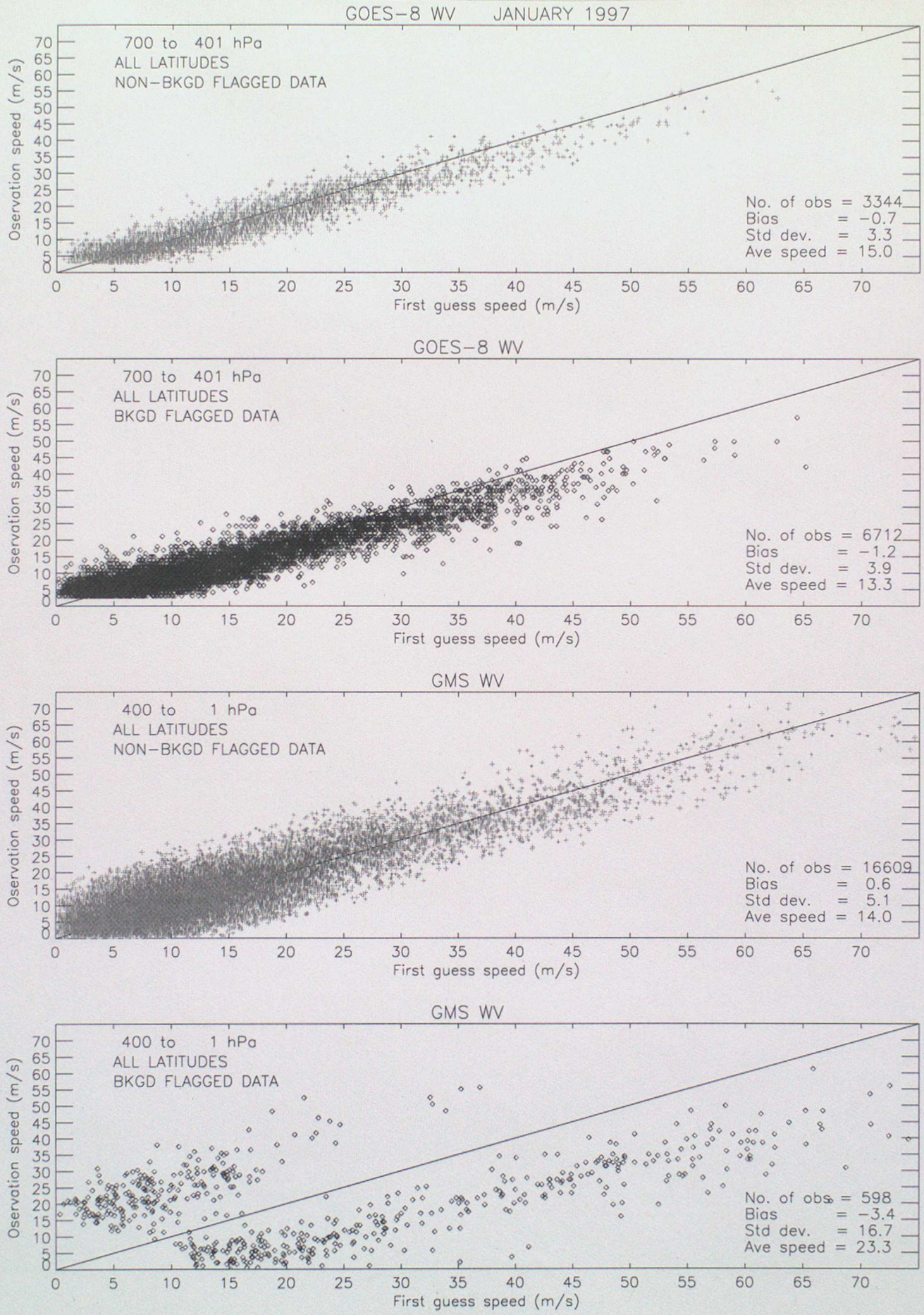
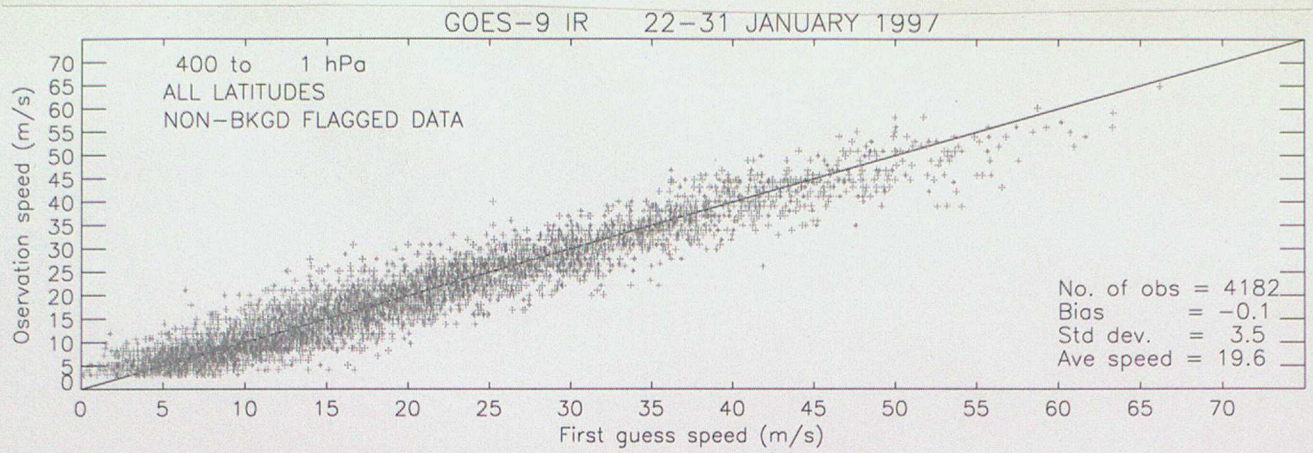
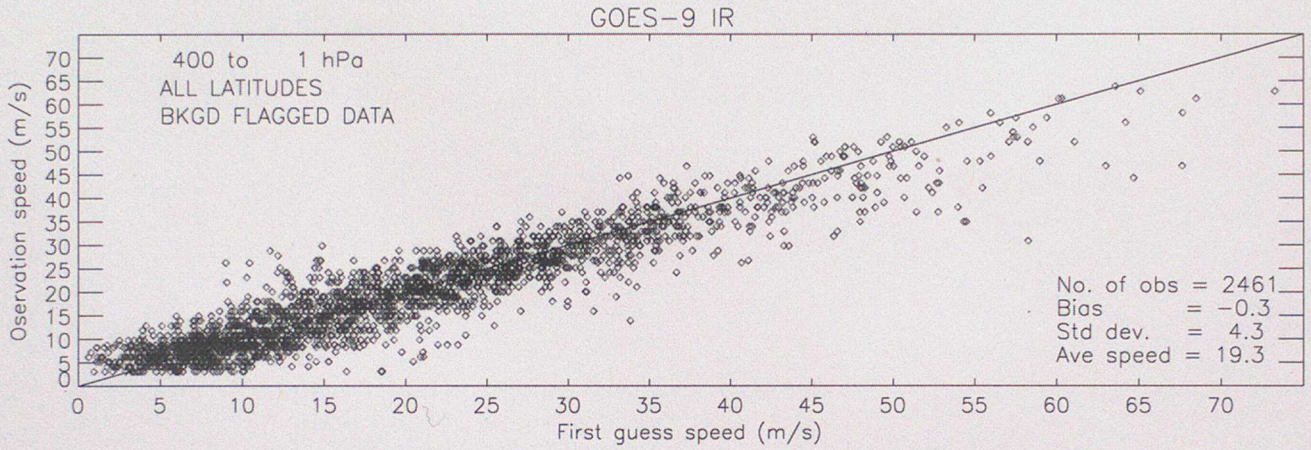
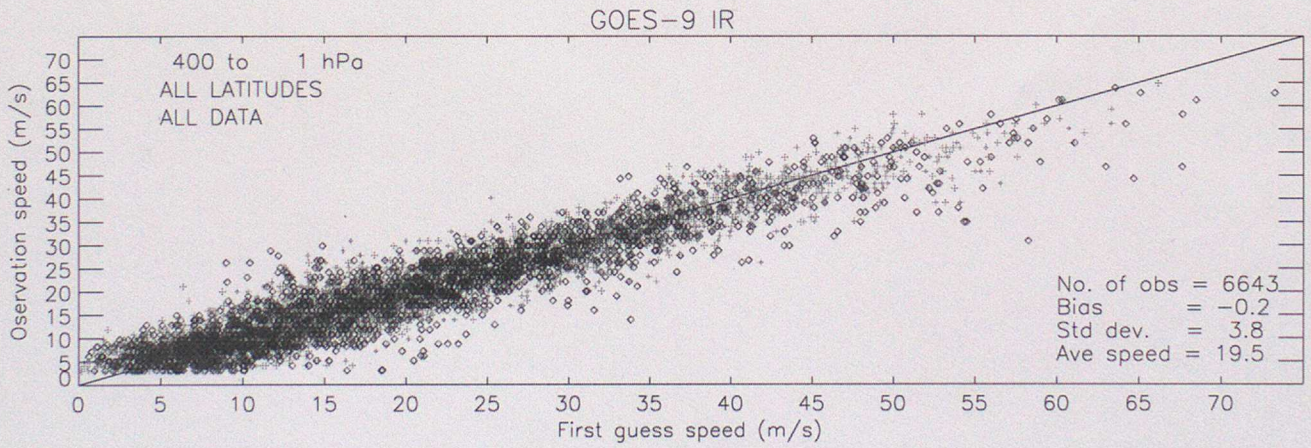


Fig. 15(a). Scatter plots of O vs B wind speed to investigate GOES height reassignment: GOES-9 IR, non-background-flagged data, background-flagged data, all data; Meteosat IR, all data, 22–31 January 1997: 1–400 hPa.







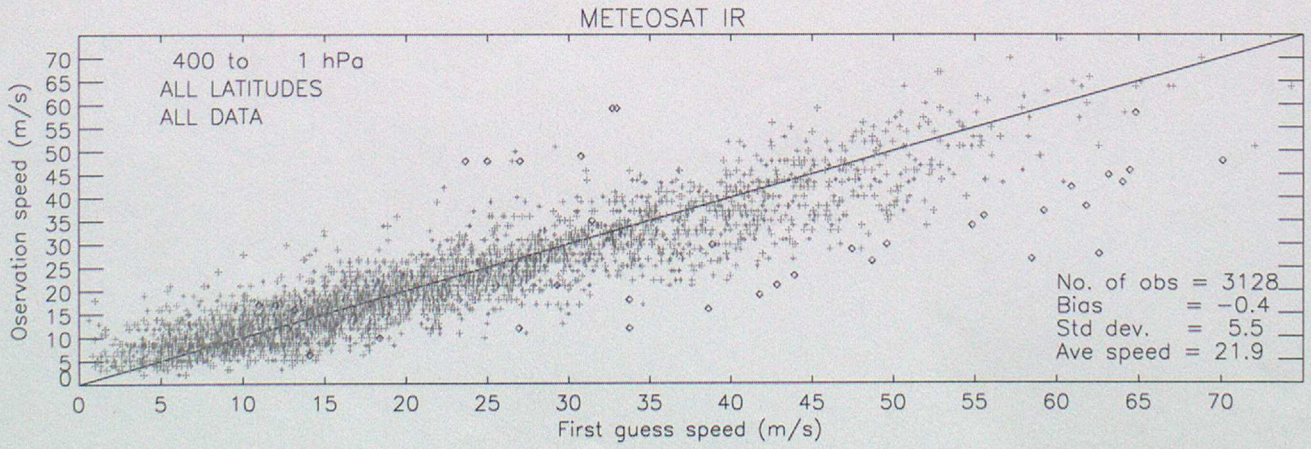
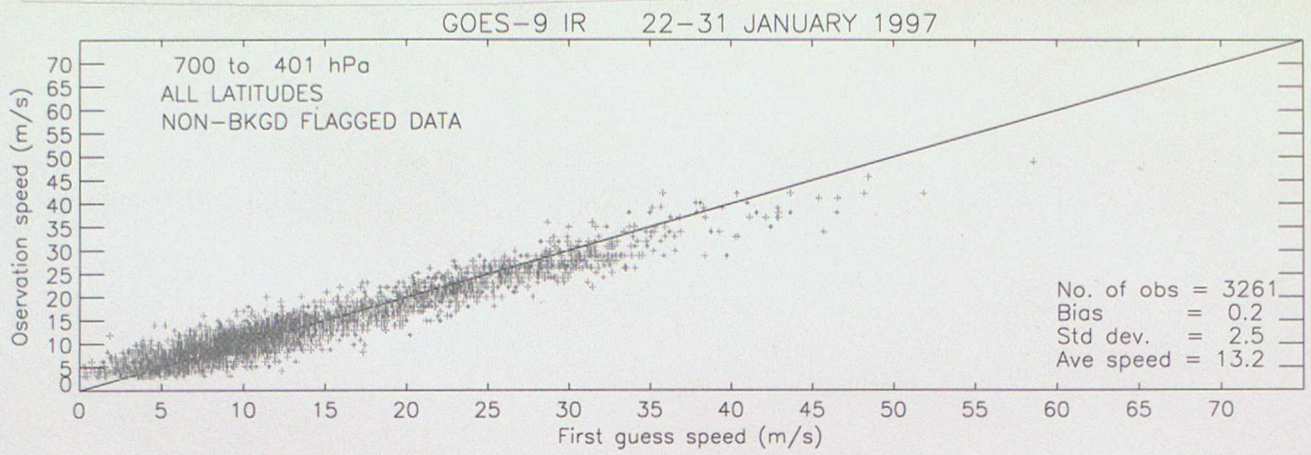
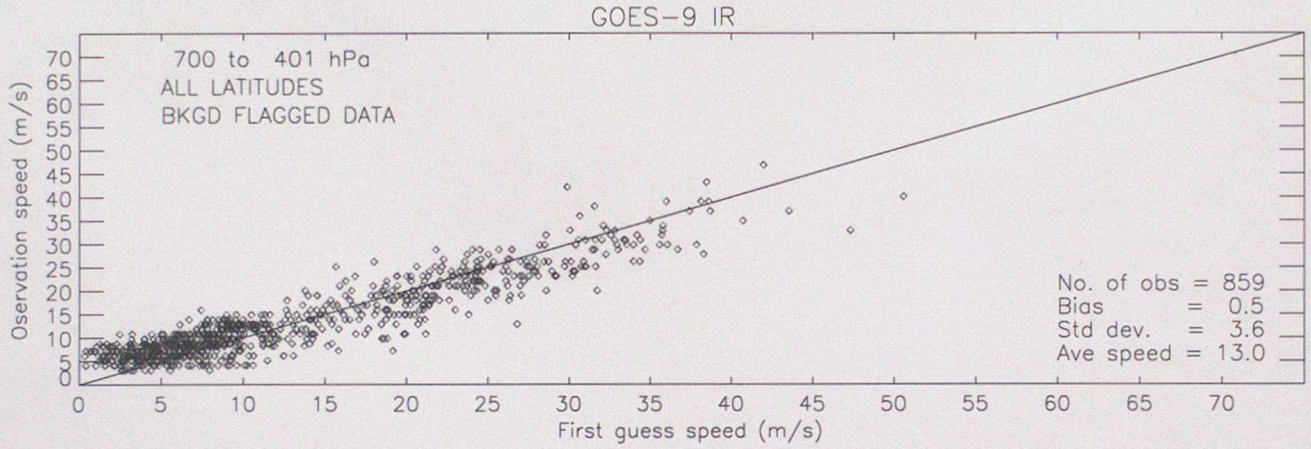
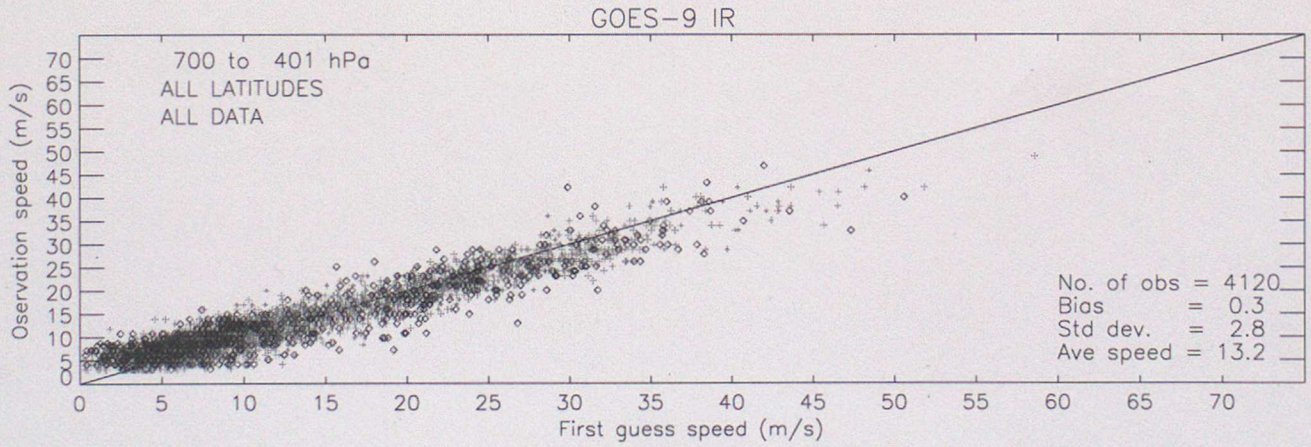


Fig. 15(b). Scatter plots of O vs B wind speed to investigate GOES height reassignment: GOES-9 IR, non-background-flagged data, background-flagged data, all data; Meteosat IR, all data, 22–31 January 1997: 401–700 hPa.







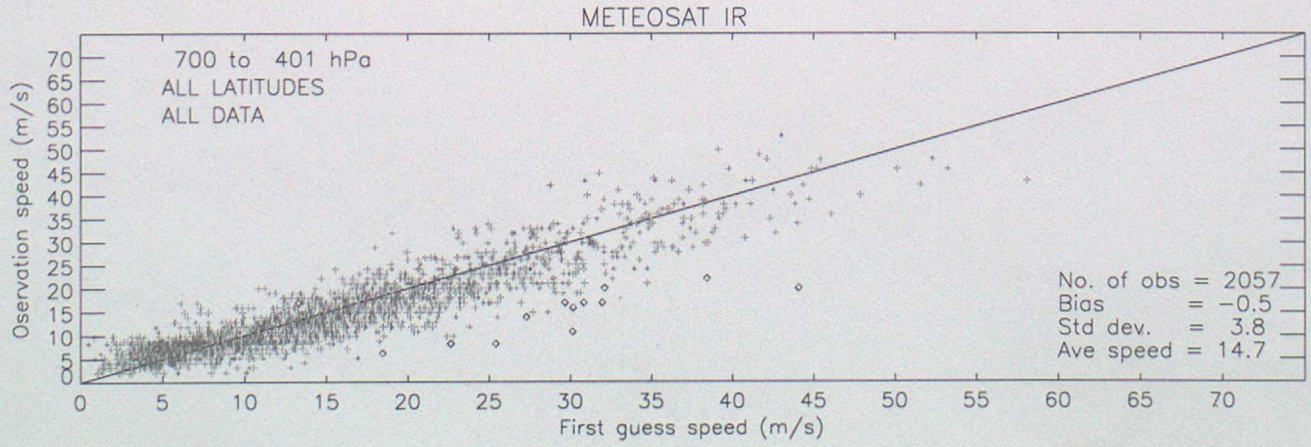
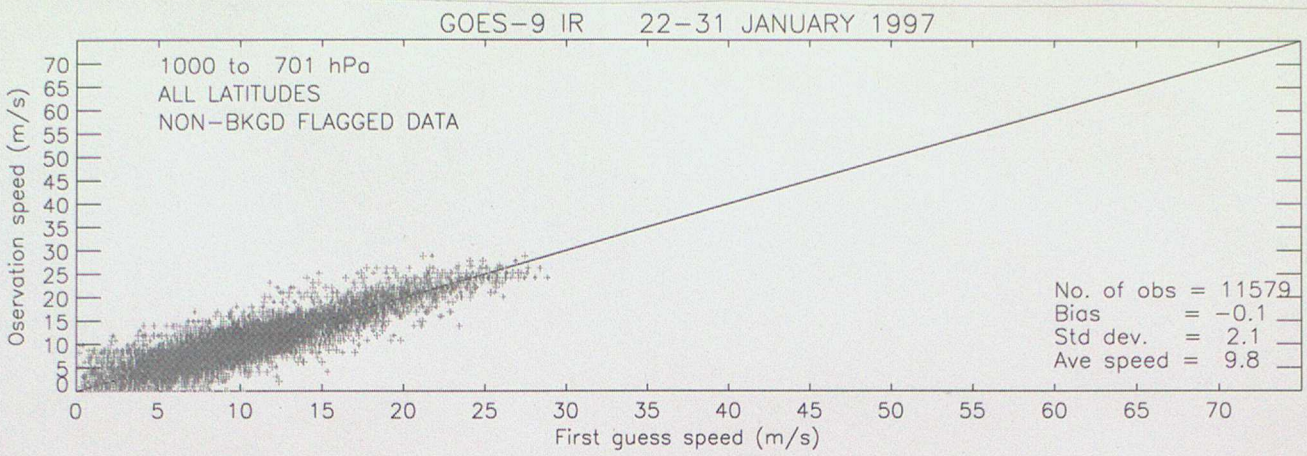
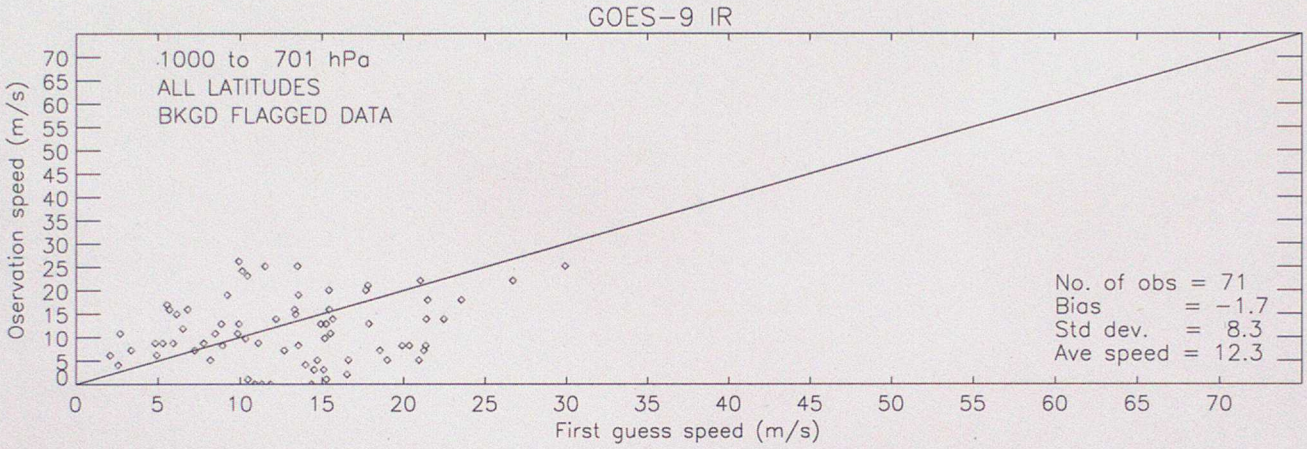
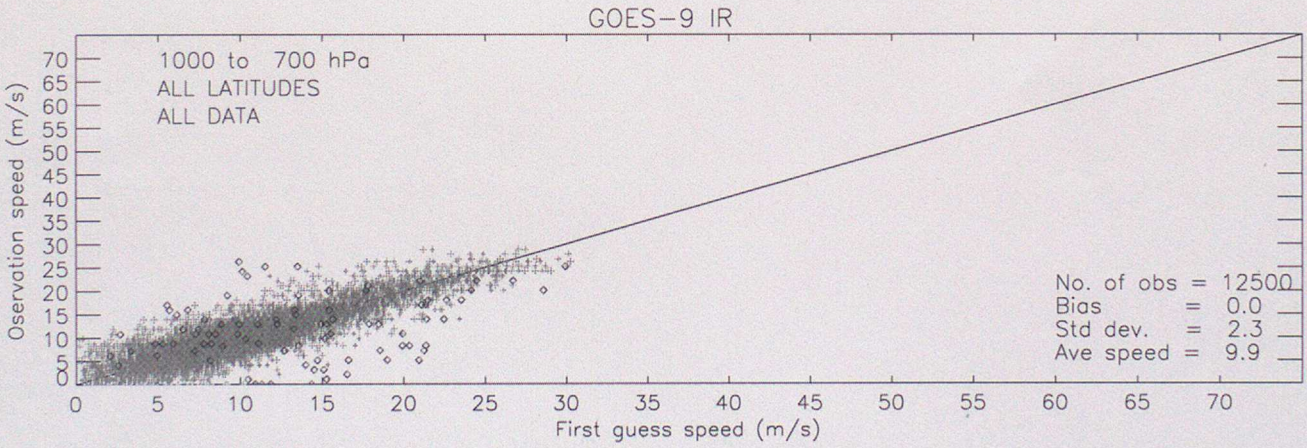


Fig. 15(c). Scatter plots of O vs B wind speed to investigate GOES height reassignment: GOES-9 IR, non-background-flagged data, background-flagged data, all data; Meteosat IR, all data, 22–31 January 1997: 701–1000 hPa.







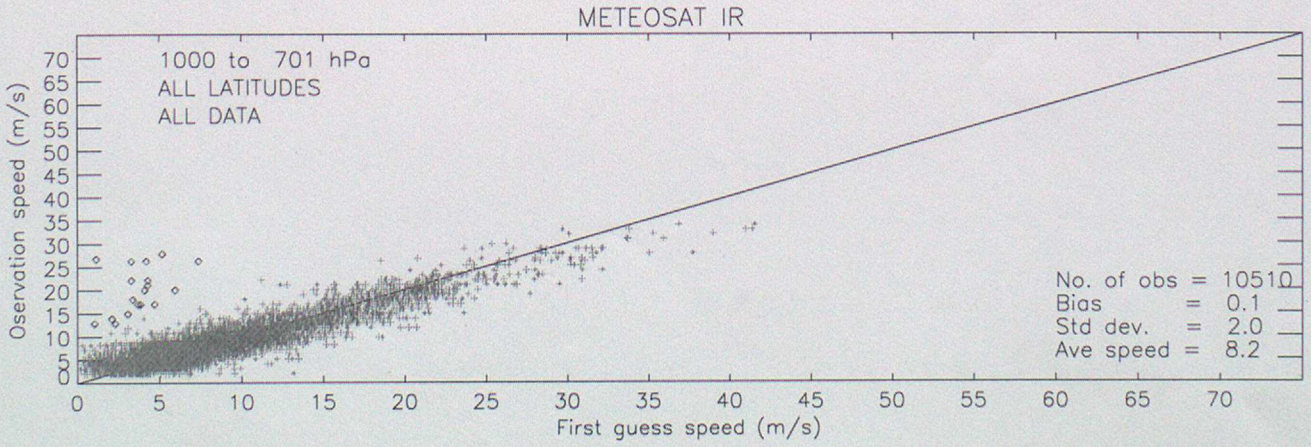
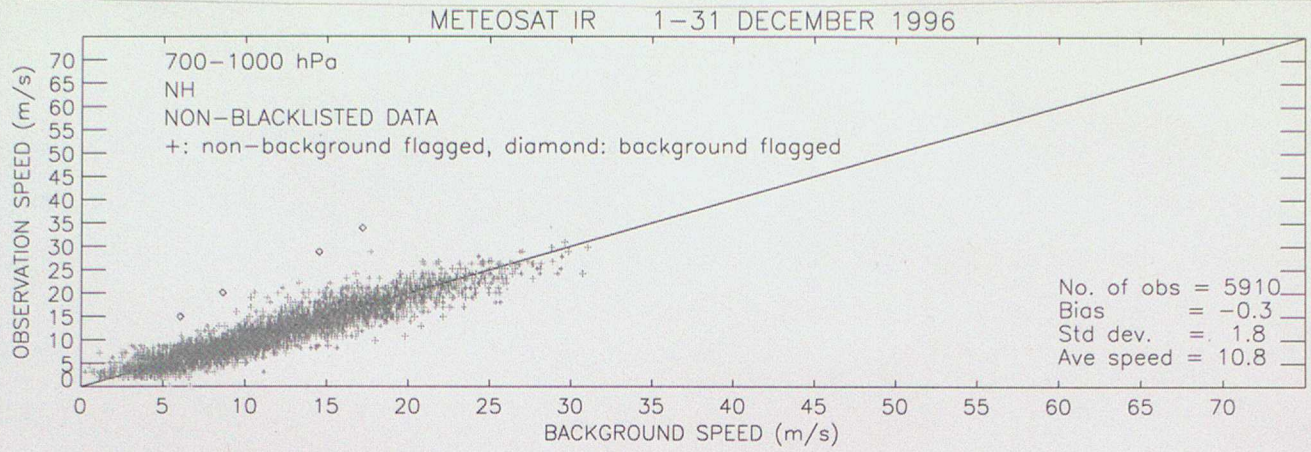
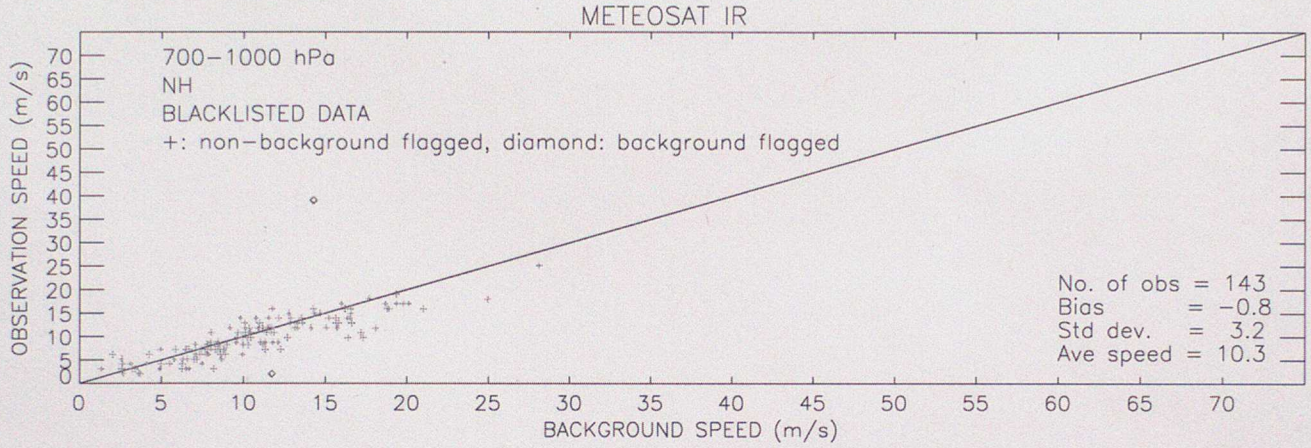
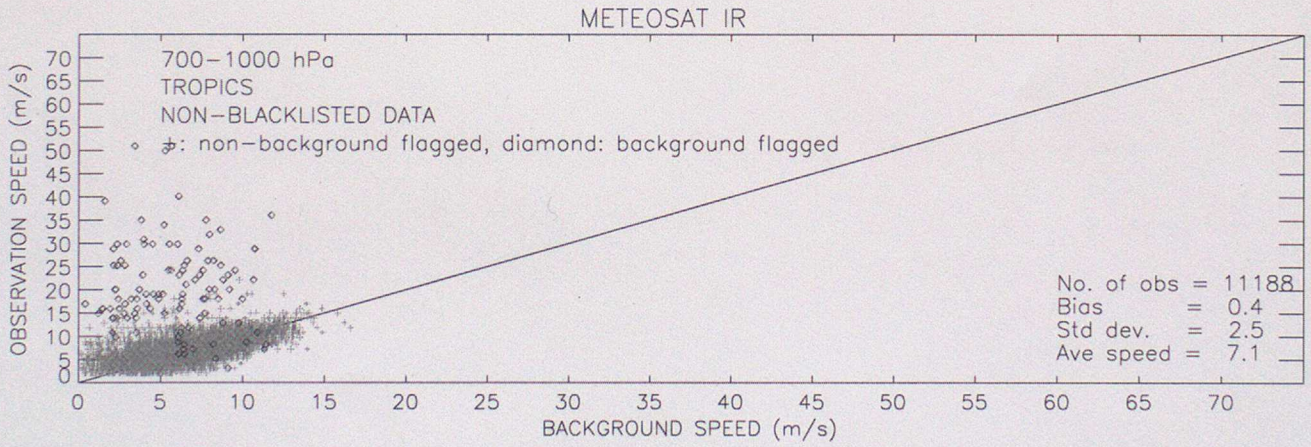


Fig. 16(a). Scatter plots of O vs B wind speed for non-blacklisted and blacklisted data at low and medium levels (LL, ML) for different satellite winds, 1–31 December 1996, distinguishing between background-flagged and non-background-flagged data: Meteosat LL IR, NH, TR.







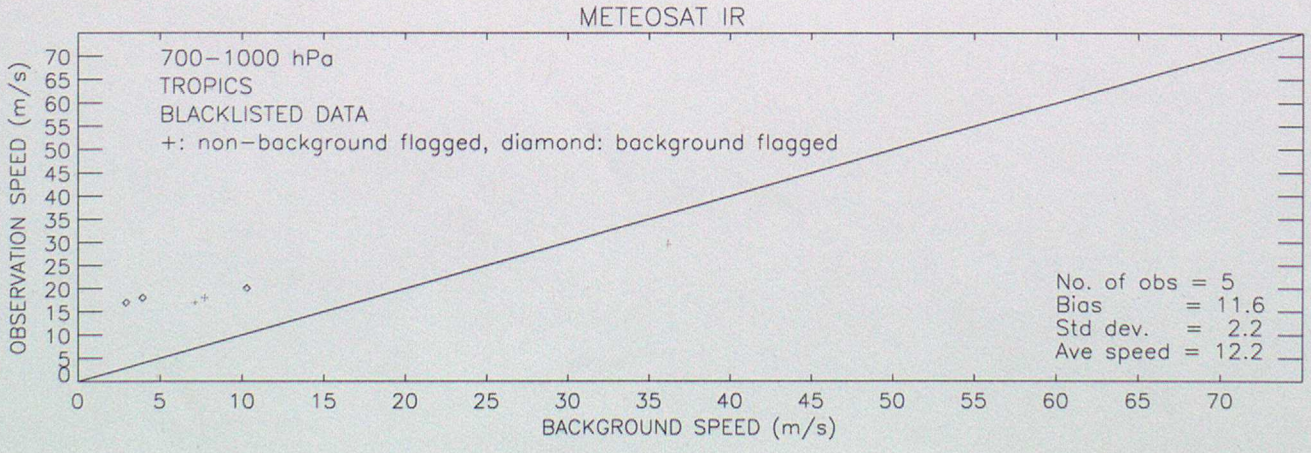
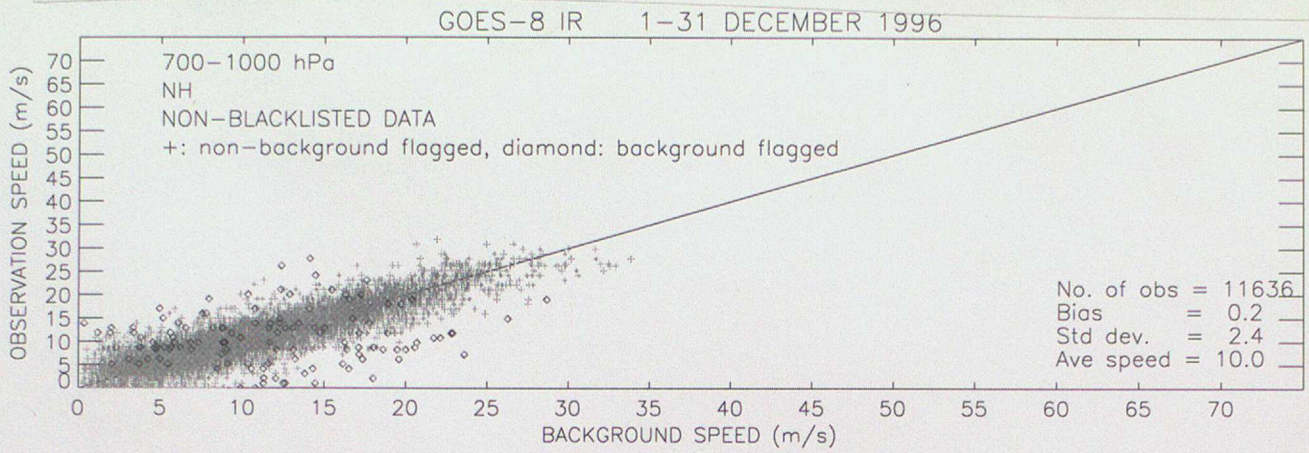
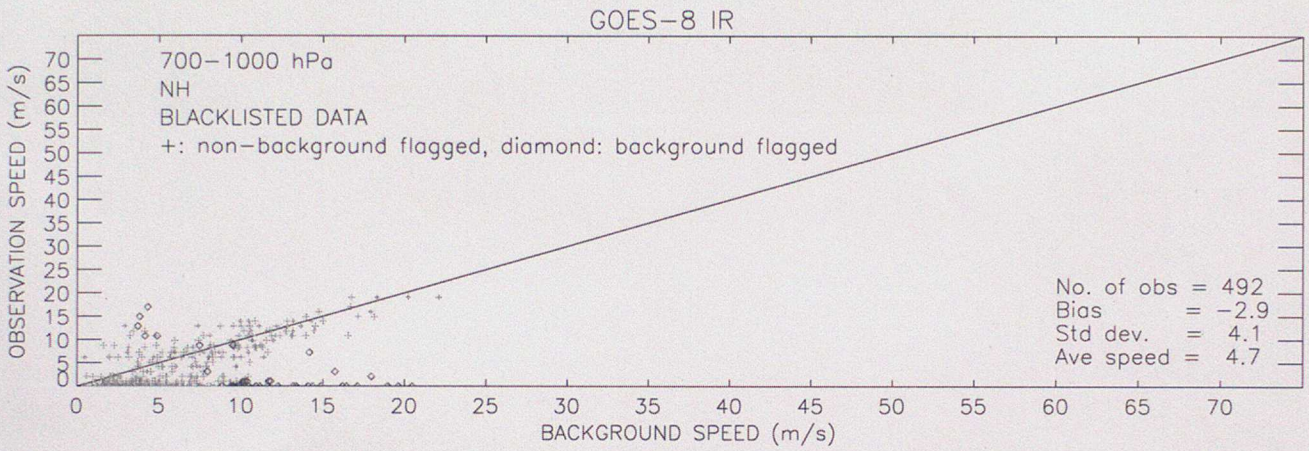
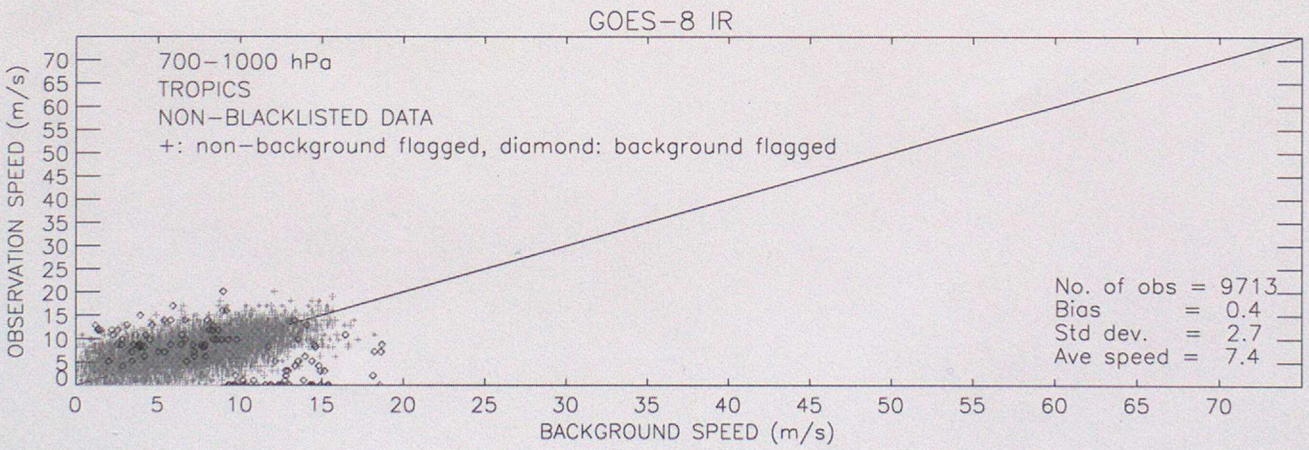
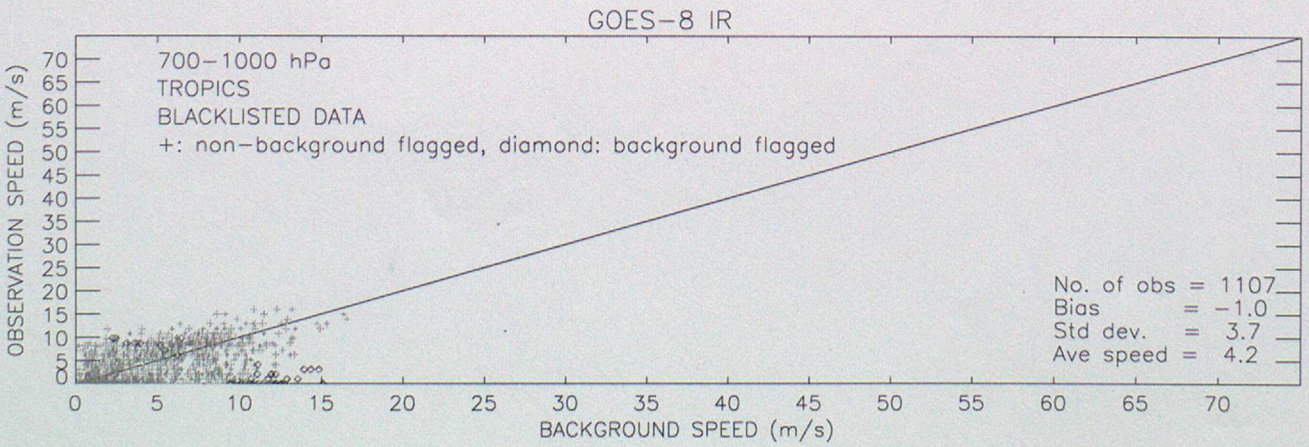



Fig. 16(b). Scatter plots of O vs B wind speed for non-blacklisted and blacklisted data at low and medium levels (LL, ML) for different satellite winds, 1–31 December 1996, distinguishing between background-flagged and non-background-flagged data: GOES-8 LL IR, NH, TR.